Groundwater at the INEEL

Introduction

The eastern Snake River Plain Aquifer is as important to the people who live in eastern Idaho as the land itself. It supplies about 2.5 billion gallons of groundwater every year for irrigation and industry, and is the sole source of drinking water for most of the people living on the plain. Without the aquifer, the high-desert environment of eastern Idaho would support far fewer people.

Most of the water in the eastern Snake River Plain Aquifer is clean and requires no chlorination to make it safe to drink. However, human activities on the eastern Snake River Plain have introduced contamination into the aquifer. One source of contamination is the Idaho National Engineering and Environmental Laboratory (INEEL), which has contaminated portions of the aquifer beneath the INEEL with hazardous chemicals and radioactive substances.

Students collect samples from the Big Lost River while participating in watershed management studies at the INEEL

At present, groundwater leaving the INEEL's boundaries meets safe drinking water standards, and does not pose a risk to water users in neighboring communities and farms. To ensure that groundwater leaving the INEEL's boundaries continues to meet drinking water standards, cleanup work is underway to remove contaminants from the aquifer and to prevent other contaminants from entering the aquifer. In addition, the safety of human health and the environment at the INEEL, and federal and state law, requires the U.S. Department of Energy to clean up the aquifer beneath the INEEL to meet safe drinking water standards.

This fact sheet describes aquifers in general, and the eastern Snake River Plain Aquifer in particular. Where aquifer contamination exceeds or is predicted to exceed drinking water standards at the INEEL, the fact sheet outlines the sources and extent of the contamination, and summarizes ongoing and planned cleanup work. The discussion includes the new technologies that are being researched and developed to increase understanding, improve management, and clean up contamination in the eastern Snake River Plain Aquifer and elsewhere. ❐

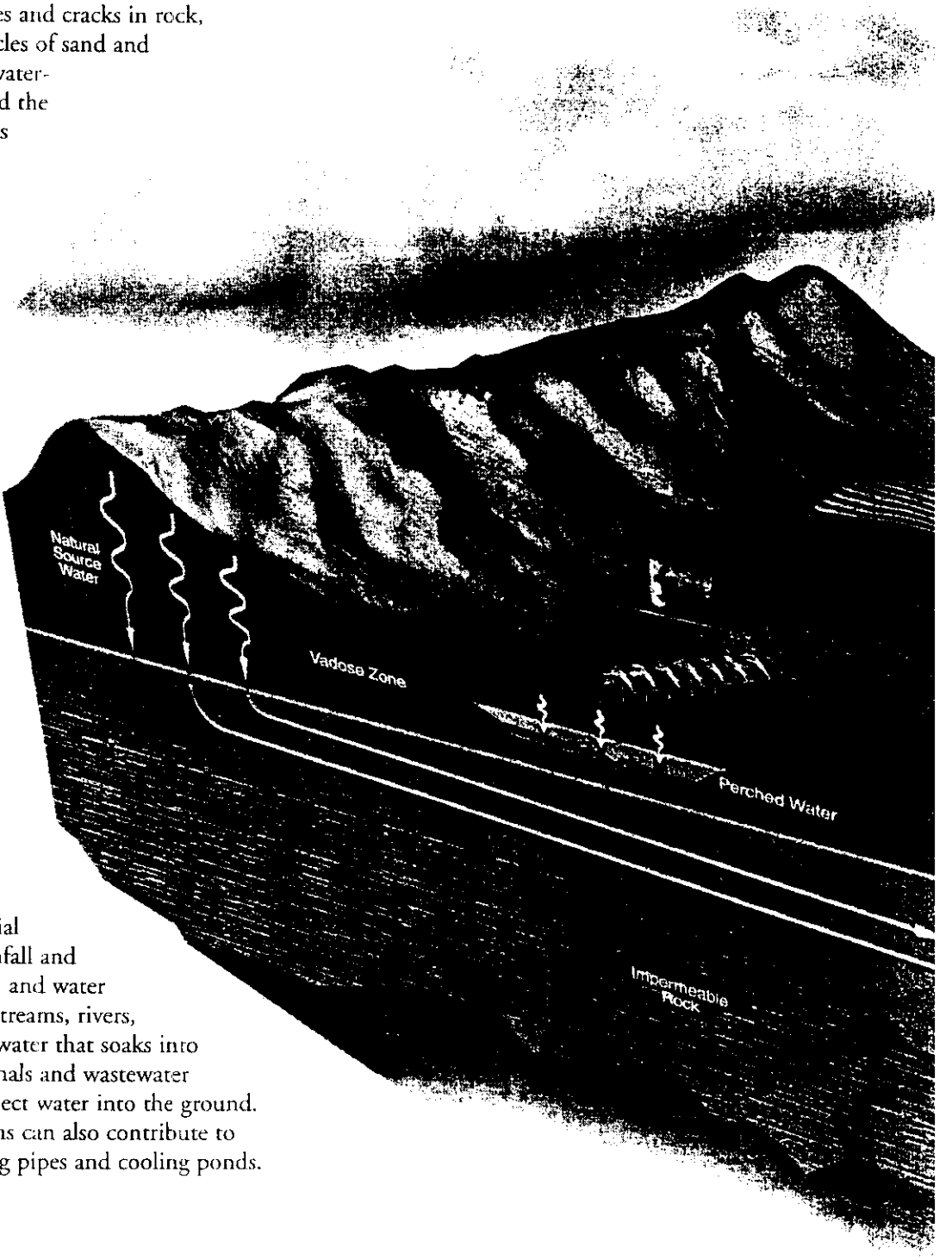
Aquifers and Groundwater

An aquifer is a layer of water-saturated rock or soil through which water flows in a quantity useful to people (see Figure 1). Water in aquifers flows through pores and cracks in rock, and between particles of sand and soil. The layer of water-saturated rock in the aquifer is called the zone of saturation, because the pores are filled mostly with water. The ground above the aquifer is called the zone of aeration, because the pores in it are filled mostly with air. The zone of aeration is also referred to as the vadose zone, from the Latin *vadum*, meaning shallow.

How Aquifers Receive Their Water

Water that soaks into the ground is called groundwater. If a sufficient quantity of water enters the ground, it will continue percolating downward past the root zone and zone of evaporation until it encounters an impermeable layer. Once groundwater can no longer move down, it fills pores in the rock and forms a zone of saturation.

Groundwater has natural and artificial sources. Natural sources include rainfall and snowmelt that soak into the ground, and water that seeps into the ground beneath streams, rivers, and lakes. Artificial sources include water that soaks into the earth beneath irrigated fields, canals and wastewater drainfields, and wells designed to inject water into the ground. Industrial facilities with water systems can also contribute to groundwater, such as through leaking pipes and cooling ponds.



Water Flow in Aquifers

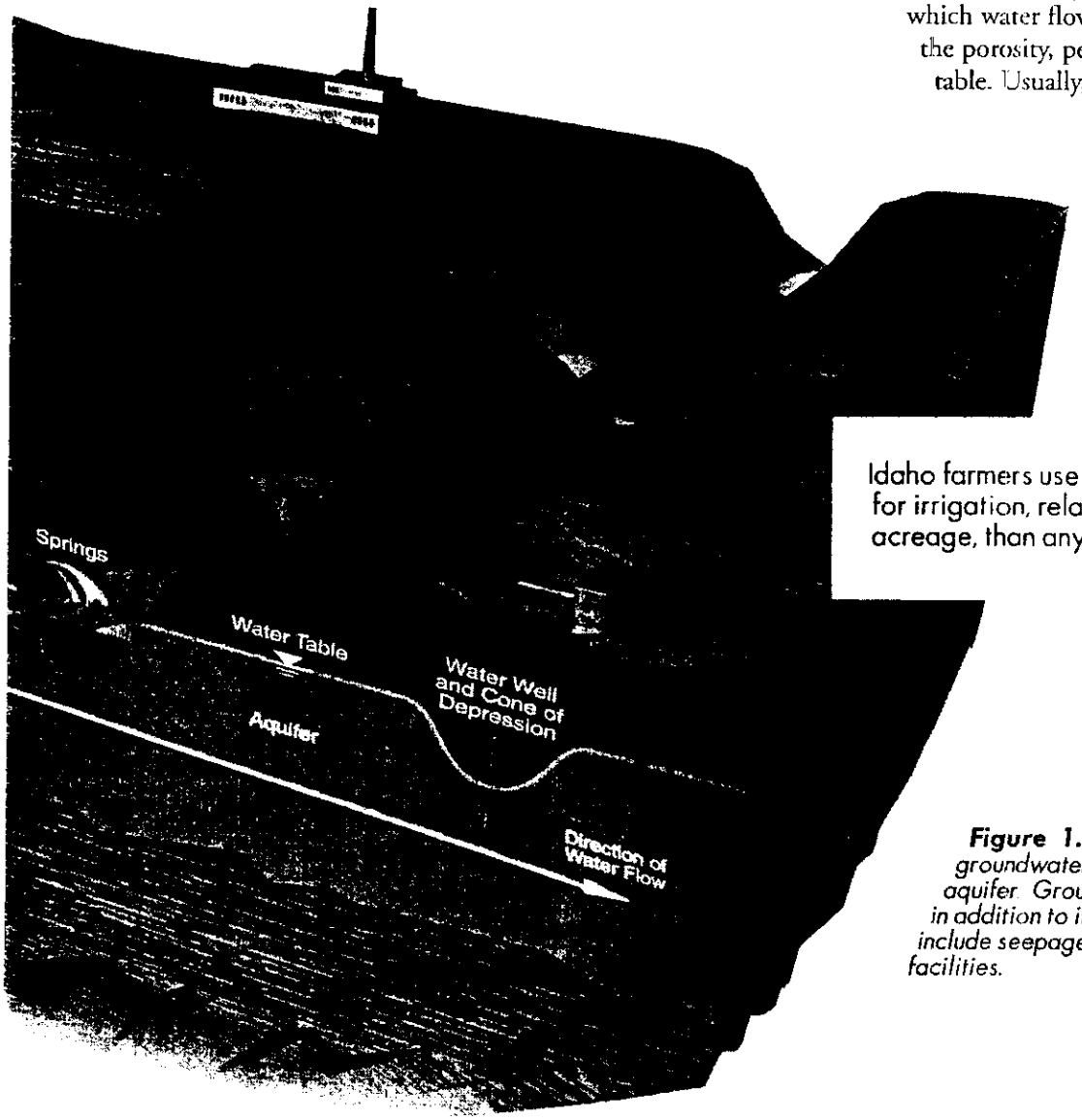
Groundwater enters, flows through, and leaves an aquifer in much the same manner as rainwater flows down slopes, fills lakes, and overflows riverbanks. In both cases the primary force acting on water flow is gravity.

In the humid East, aquifers often fill up until the saturated zone is at or near the earth's surface. In the arid West, aquifers can be very deep. Where rock layers slope, groundwater seeks the lowest point of the layers.

Many times these sloping rock layers outcrop at the earth's surface, such as at the base of a mountain range, or where a canyon has sliced deep into the earth's surface. There groundwater can leave the aquifer as a spring or seep.

Aquifer Geology

For rock to serve as an aquifer it must be both porous and permeable: porous means it has many empty spaces which can hold water; permeable means these spaces are connected so that water can move between them (see Figure 2). Sand, gravel, and volcanic rubble make excellent aquifers because they have high porosity and permeability. Rocks such as granite and claystone make poor aquifers, unless fractured by geologic activity, because they are practically impermeable. The rate at which water flows within an aquifer depends upon the porosity, permeability, and slope of the water table. Usually, water flows very slowly in aquifers, perhaps only a few inches per day.



Idaho farmers use more groundwater for irrigation, relative to total farmed acreage, than any other state.

Figure 1. *Artist's rendition showing how groundwater enters and leaves a typical aquifer. Groundwater often has artificial sources in addition to its natural sources. Artificial sources include seepage from irrigated fields and industrial facilities.*

Wells and Water Tables

Aquifers are either confined or unconfined, depending upon the permeability of the rock layers above them (see Figure 3). Confined aquifers are capped by impermeable layers, and unconfined aquifers are not. Wells drilled into confined aquifers can be self-flowing if water fills the aquifer at an altitude higher than the top of the well. Self-flowing wells are called artesian wells, for the village of Arteis (now Artois), France, where this phenomenon was first recorded. Wells drilled into unconfined aquifers must be pumped to produce water, because the water is not under pressure.

The top surface of the saturated zone in an unconfined aquifer is called the water table. A water table rises when more water is flowing into the aquifer than leaving the aquifer, and lowers when more water is leaving than entering. Water tables can fluctuate seasonally, rising during wet months and lowering during dry months.

The scientific symbol used to identify the water table is: ▽

Human activities can substantially change water tables. For example, water seeping into the ground beneath irrigated fields can raise the water table, and wells drawing water from the aquifer can lower the water table. A well often draws down the water table in its immediate vicinity, in what is called a cone of depression (see Figure 1). If the water table drops beneath the bottom of the well, the well runs dry.

Perched Water Zones

Groundwater percolating downward frequently encounters areas of relatively impermeable material, such as clay, before it reaches the aquifer. Groundwater that collects above one of these resistant layers forms a perched water zone, so called because it sits above the aquifer like a bird perched on a tree limb (see Figure 1). Perched water slowly leaks downward to the aquifer. Perched water is often present beneath reservoirs, irrigated fields, or anything that discharges large quantities of water, such as industrial facilities. Perched water zones disappear over time after the reservoir has emptied, irrigation has ceased, or the facility has shut down. Usually perched water zones do not contain enough water to supply useful quantities of drinking or irrigation water. ❐

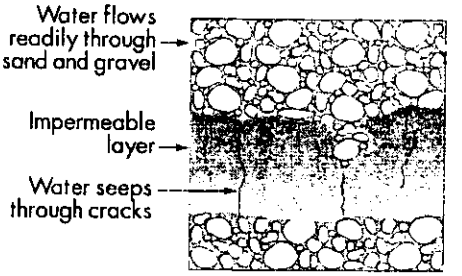


Figure 2. *Layers of clay and compacted sediments are less permeable than sand and gravel, and can impede water flow.*

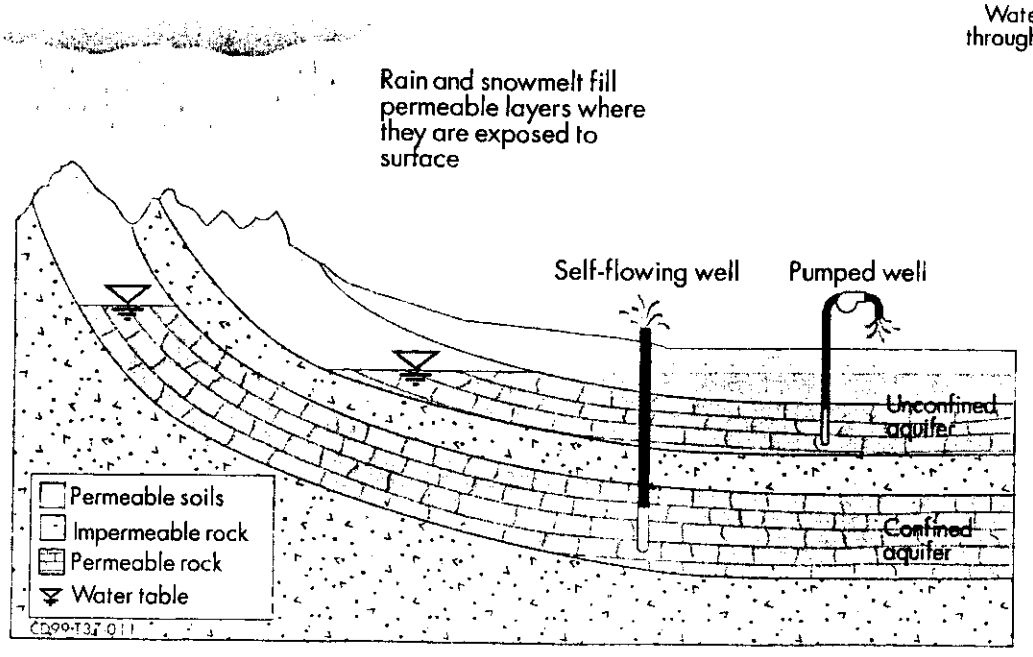


Figure 3. *Confined aquifers are capped by impermeable layers. Unconfined aquifers are essentially open to the earth's surface.*

The Snake River Plain Aquifer

The eastern portion of the Snake River Plain Aquifer begins near Ashton, Idaho, and flows southwestward to King Hill, Idaho, in a broad crescent beneath the eastern Snake River Plain (see Figure 4). Because the plain gently slopes from northeast to southwest, the aquifer likewise drains to the southwest, to springs along the Snake River. The aquifer contains an estimated 1 billion acre-feet of groundwater, about 600 times as much water as is held by American Falls Reservoir. An acre-foot is enough water to cover an acre of land to a depth of one foot, or about enough to irrigate an acre of alfalfa in eastern Idaho for 10 days in the summer. Only about one-fifth of the aquifer's capacity is considered economically available – groundwater at great depth is too expensive to pump or may contain excessive minerals.

At the center of the plain the aquifer is about 4,000 feet thick, and at the margins it thins to a few hundred feet thick. The depth from the surface to the water table varies from as little as 6 feet at Mud Lake to about 1,000 feet near the center of the plain. Beneath the INEEL, the aquifer slopes downward from a depth of about 200 feet at the INEEL's northern border to about 1,000 feet at the southern border. Water flows 5 to 10 feet per day in the eastern Snake River Plain Aquifer, on average. Compared to most aquifers this is very fast; however, water that enters the aquifer near Ashton still requires 200 to 300 years to reach King Hill.

Most of the water flow in the eastern Snake River Plain Aquifer occurs in an active layer, usually the top 200 feet of the zone of saturation. Groundwater beneath the active layer flows much more slowly and is generally of lesser quality. At depth, the eastern Snake River Plain Aquifer joins with the western portion of the Snake River Plain Aquifer. The western portion underlies the Snake River Plain from King Hill, Idaho, to the vicinity of Nyssa, Oregon. There is little or no water flow between the two regional aquifers because the Snake River cuts through the Snake River Plain Aquifer's active zone.

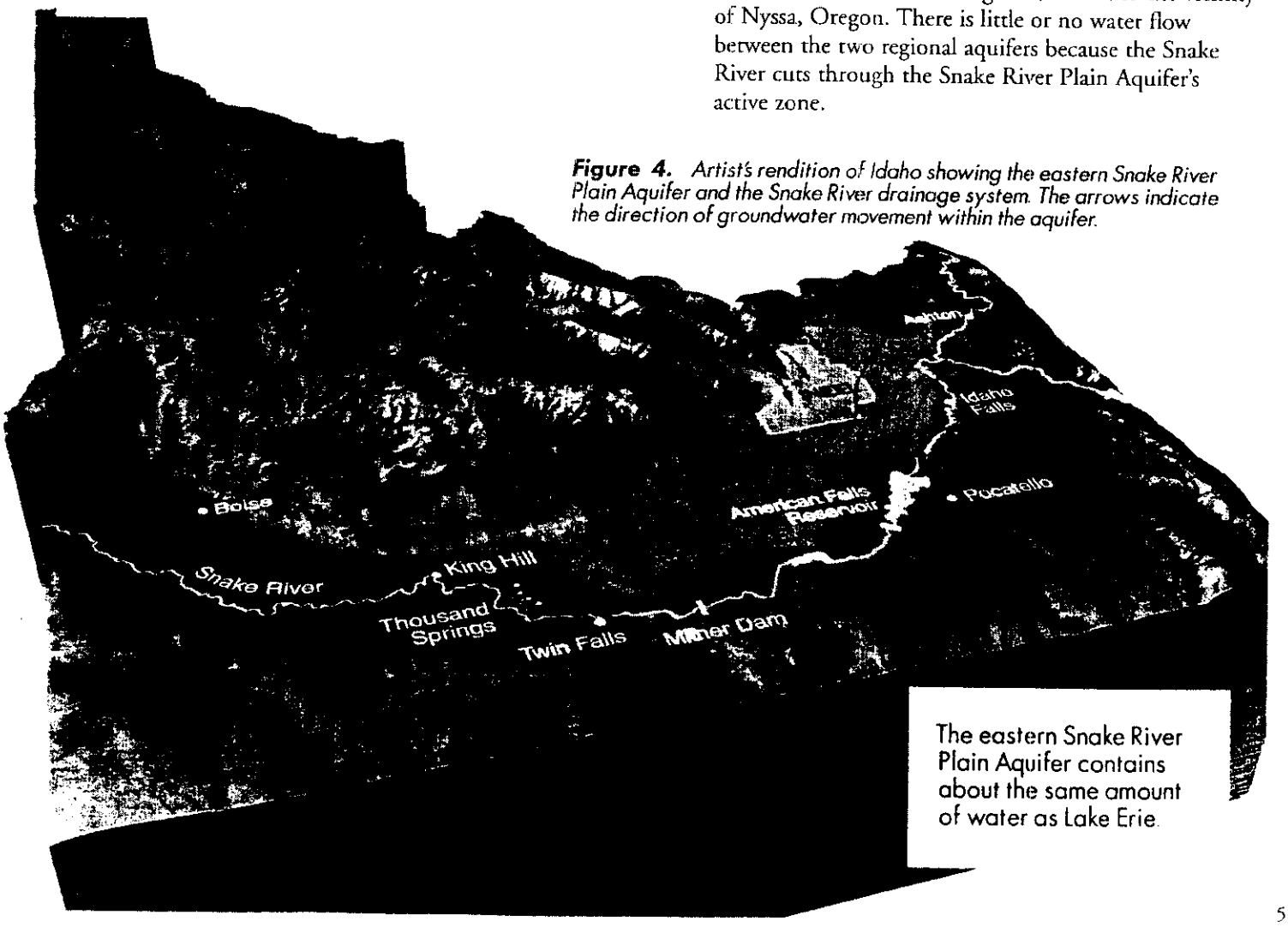


Figure 4. *Artist's rendition of Idaho showing the eastern Snake River Plain Aquifer and the Snake River drainage system. The arrows indicate the direction of groundwater movement within the aquifer.*

Geology of the Aquifer

Many aquifers east of the Rocky Mountains lie in uniform rock or sediment layers. The eastern Snake River Plain Aquifer, in contrast, occupies complex layers of fractured basalt, rock and rubble, and thin layers of sediments. The base of the aquifer is a very thick layer of relatively impermeable volcanic rock. The aquifer is notably irregular because of fracturing – one well might produce 1,000 gallons a minute, while another 30 feet away is a dry hole.

The basalt layers in total vary from 2,000 to 4,000 feet in thickness on much of the eastern Snake River Plain, thinning towards the edges. Each individual layer is about 20 to 30 feet thick, the upper 3 to 6 feet typically consisting of highly porous and permeable rubble. As much as 50 percent of the rubble's volume may consist of open pores through which water can flow.

Sedimentary interbeds were deposited by wind, and ancient streams and rivers. They are generally less permeable than basalt layers and tend to impede the flow of water. When there is a source of surface water percolating into the aquifer, perched water zones often form above these sedimentary interbeds.

Basalt fractures create numerous passageways where groundwater percolates downward. Many of the rivers that enter the plain from its northern side, such as the Big and Little Lost Rivers, begin to lose water to underlying soils and fractured basalts as soon as they enter the plain, and quickly disappear, hence the name Lost.

Figure 5. *The Big Lost River, Little Lost River, and Birch Creek are examples of what geologists call "losing" streams. These water courses lose water to the porous subsurface and eventually disappear.*

Source and Fate of Water in the Aquifer

Groundwater in the eastern Snake River Plain Aquifer originates predominantly as mountain snowmelt and to a lesser extent as precipitation onto the plain. Groundwater leaves the aquifer through seepage, springs, and wells (see Figure 6). One concentration of springs is immediately upstream of and beneath American Falls Reservoir. A second concentration occurs where the Snake River cuts through the water table below Milner Dam (see Figure 4). This concentration includes 11 of the 65 largest springs in the United States. At Thousand Springs, about 6.8 million acre-feet of groundwater returns annually to the Snake River, four times as much water as the capacity of American Falls Reservoir. Though the water in the Snake River is almost entirely diverted to irrigation at Milner Dam, Thousand Springs nearly replenishes the river below Twin Falls.

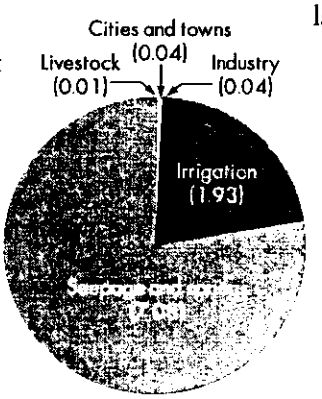
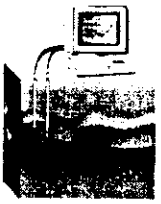


Figure 6. *Fate of water that leaves the eastern Snake River Plain Aquifer (approximate annual quantities in million acre-feet).*

Before occupation of the eastern Snake River Plain by settlers, much of the precipitation that fell on the plain and its surrounding mountains was carried directly to the Snake River by tributaries. Since then, irrigation projects have since diverted most of the surface water onto fields. Irrigation water that didn't run off, evaporate, or transpire from plants, percolated from the fields into the aquifer, substantially raising its level.

The aquifer was first used for irrigation in the Mud Lake vicinity in the 1920s. Elsewhere on the plain, the aquifer was too deep to economically pump until after World War II. The use of groundwater for irrigation expanded rapidly during the 1950s and early 1960s. At present, there are more than 5,000 water wells on the eastern Snake River Plain. Most wells are completed to a depth of 200 to 400 feet below the surface, and draw from the upper 100 feet of the aquifer's active zone. In some locales, extensive use of groundwater has significantly lowered the water table – as much as 200 feet in Magic Valley near Milner Dam. At other locations, irrigation seepage has raised the water table an average of 50 feet. ❐

Measuring, Monitoring, and Modeling



Aquifers and groundwater are monitored to determine the nature and extent of contaminants that pose a risk to human health and the environment. Groundwater contamination is measured by taking water samples from monitoring wells. The presence and concentration of contaminants in a groundwater sample are determined in a laboratory. Knowledge of aquifer and contaminant characteristics, coupled with computer modeling of groundwater and contaminant movement, helps to predict how contaminants might spread in the aquifer.

Locations of INEEL Monitoring Wells

More than 500 wells are used to monitor groundwater for contamination at and around the INEEL (see Figure 7).

Most of these monitoring wells are located in the immediate vicinity of contaminant sources. Some wells are located upgradient (the groundwater equivalent of upstream) of the INEEL, in the vicinity of Mud Lake, and measure the water quality in the aquifer before it flows under the INEEL. Other wells are located downgradient of the INEEL, as far west as Thousand Springs. Monitoring is performed by federal and state agencies, along with DOE's contractors.

Some contaminated groundwater at the INEEL is in perched water zones or is in transit through the vadose zone. These areas are also monitored.

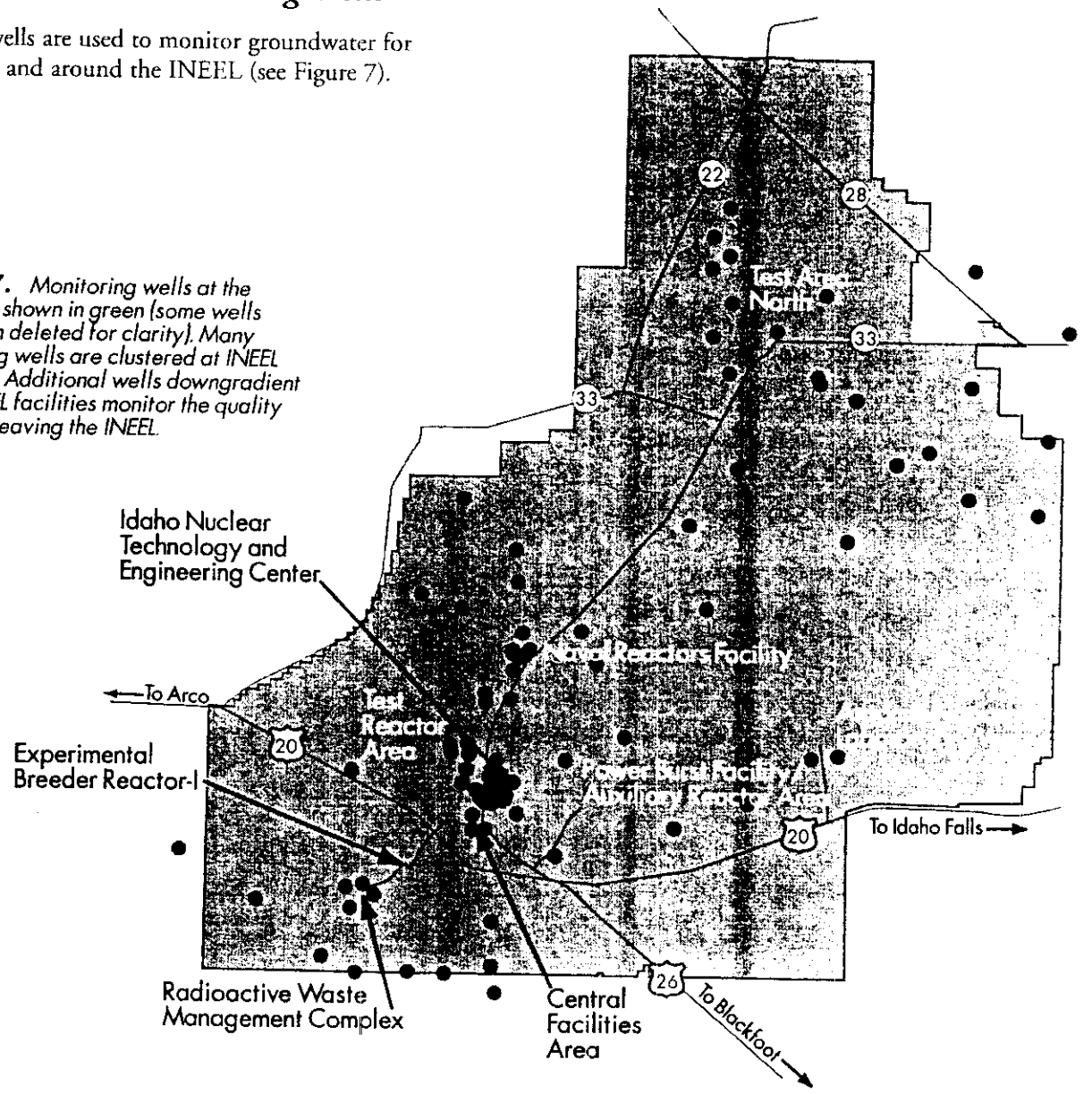


Figure 7. *Monitoring wells at the INEEL are shown in green (some wells have been deleted for clarity). Many monitoring wells are clustered at INEEL facilities. Additional wells downgradient from INEEL facilities monitor the quality of water leaving the INEEL.*

Types of Monitoring Wells

Several types of wells are used to measure groundwater contamination in the eastern Snake River Plain Aquifer. The most common are the screened well and the open-bore well (see Figure 8).

Screened wells have closely-spaced slots to allow water in while keeping sediment out. They are often are designed to sample the top part of an aquifer (though they can sample a discreet interval anywhere in the aquifer) because many contaminants tend to remain at the top of the aquifer and spread downgradient in a broad, thin plume. Screened wells are often located close to the source of contamination. Because contaminant plumes are three-dimensional, can travel at unexpected depths, and detour around locally impermeable areas, many screened wells may be necessary to accurately map contaminant spread.

Open-bore wells do not contain screens and obtain water samples that are averages of large portions of an aquifer. Open-bore wells obtain water samples representative of what people are likely to pump for drinking water and irrigation water; however, they can dilute concentrated contaminant plumes with clean water drawn from uncontaminated zones.

Geologists and hydrologists must carefully select the type, location, and number of monitoring wells, and supervise their construction, to obtain accurate data on aquifer contamination. Monitoring wells are constructed to prevent cross-contamination to avoid spreading contamination between a perched water zone and an aquifer, or between two water-bearing zones in an aquifer.

It cannot be overemphasized that the eastern Snake River Plain Aquifer has considerable local variations in permeability and porosity. Monitoring wells sample only the water that is immediately adjacent to the well.

Water Sampling Methods

Water samples are taken from monitoring wells at depth intervals and frequencies determined by regulations and scientific needs. Before a sample is taken, the depth to the water table is measured and the well is purged by pumping a volume of water equal to three times the volume of the well. Purging helps to ensure that the water sample collected is representative of the groundwater in the aquifer. Measurements of the depth to the water table help to determine groundwater flow and direction, and to verify computer models that predict groundwater movement. Purged water is properly disposed of in a manner consistent with the contamination present.

Water is analyzed in the laboratory for contaminant concentrations and general characteristics. Concentrations of contaminants inform investigators about the nature of the aquifer, help verify the accuracy of computer models that predict contaminant movement, and indicate the effectiveness of cleanup efforts.

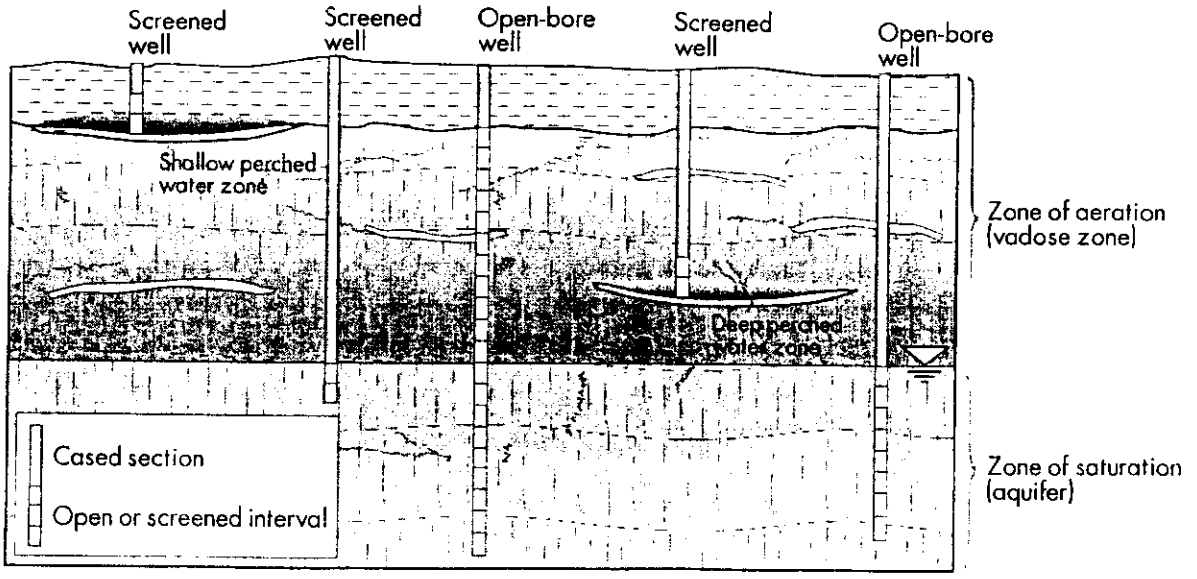


Figure 8.
Cross-section of an aquifer showing common placement of screened and open-bore monitoring wells.

For many contaminants, the Environmental Protection Agency has established a Maximum Contamination Level (MCL). The MCL, also known as the drinking water standard, is the maximum permissible level of a contaminant in water delivered to any user of a public water system. While MCLs were not specifically intended to be a standard for groundwater quality, applying MCL values as a measure of aquifer contamination levels offers a conservative and protective perspective on the nature and extent of aquifer contamination. MCLs are established for primary drinking water standards. Primary drinking water standards are those necessary to protect human health. Secondary drinking water standards were established by the EPA and are taste, odor, and appearance standards. This fact sheet is primarily concerned with primary drinking water standards.

Groundwater Modeling

Because aquifers are difficult to observe directly, scientists use sophisticated numerical models to study them. The models predict contaminant concentrations in the aquifer in the future, the pathways by which contaminants might reach humans, and the risks to human health. The models are also used to evaluate various cleanup options. An example of modeling is illustrated in Figure 9.

Because the models examine how contaminants move and where contaminants go, they are called fate and transport models.

Models incorporate key features including the contaminant source, pathways by which the contaminants might reach humans or the environment, and the physical, chemical, and biological processes that might significantly affect contaminant fate and transport. For instance, contaminant movement might be restricted if the contaminant readily binds to soils at a site.

Scientists have available an array of numerical models and data analysis tools to apply to models. Models predict if contaminants will exceed drinking water standards or other risk-based guidelines at various locations. If a model predicts that groundwater contamination will exceed acceptable values, it can be used to examine cleanup options, and to guide additional data collection efforts.

Models require assumptions about how water and contaminants travel in different rock and soils, factors that are highly variable. As a result, models may have a high degree of uncertainty, and require validation through monitoring data.

Scientists at the INEEL design fate and transport models for the INEEL and other sites across the country. Recent models include Superfund sites located in California, and Texas sites contaminated with organic chemicals. ❐

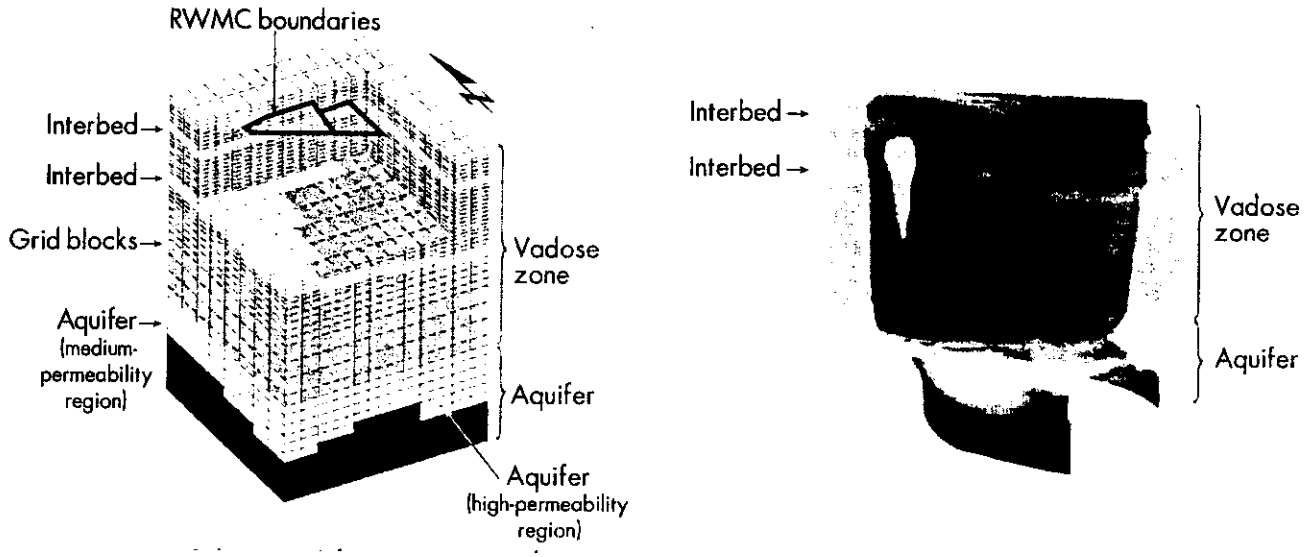


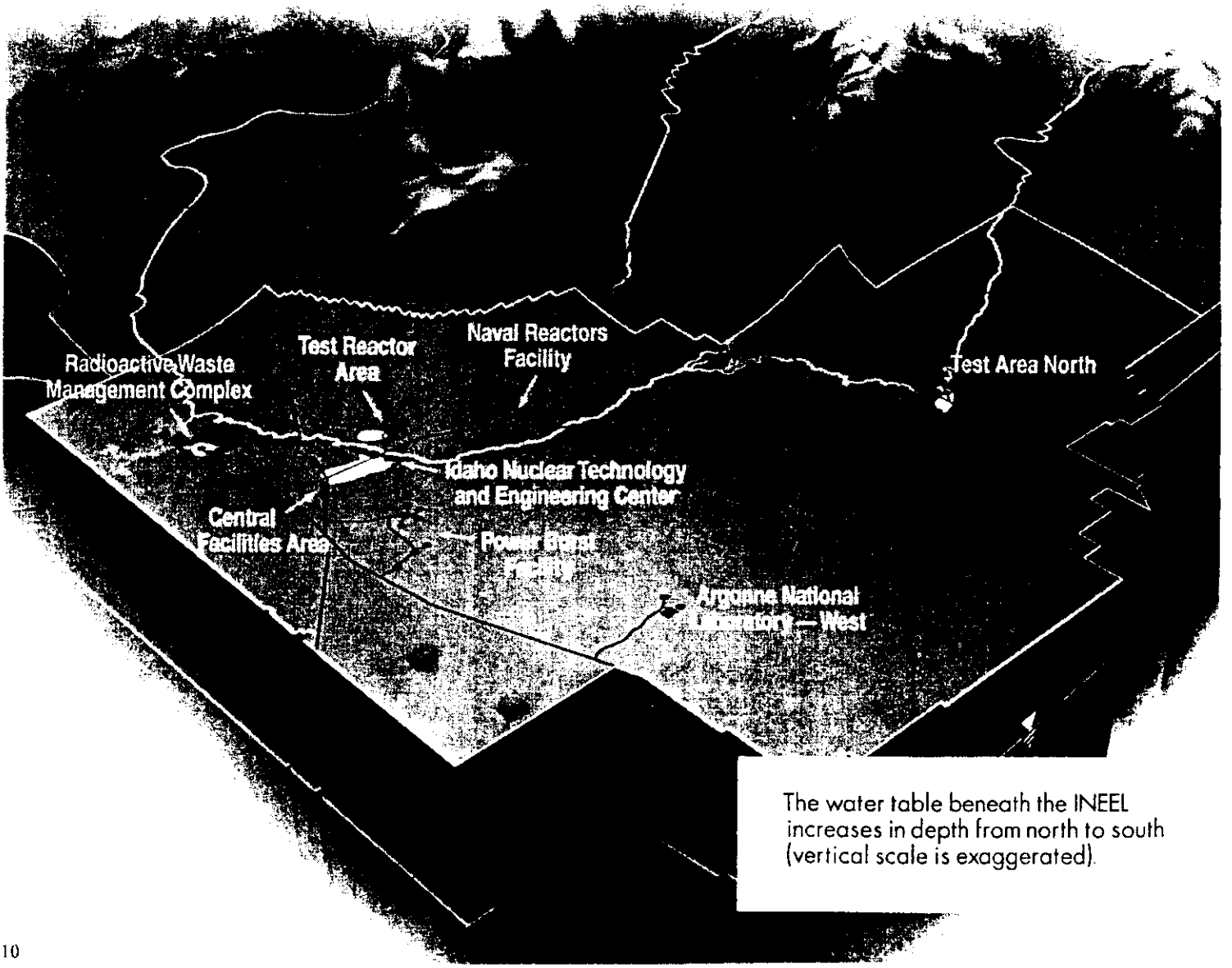
Figure 9. *Numeric modeling of carbon tetrachloride migration at the Radioactive Waste Management Complex at the INEEL. The permeability grid (on the left) is based on laboratory tests of soil and rock. This grid is used to predict the dispersion (on the right) of carbon tetrachloride in the vapor phase (shown in green) and the aqueous phase (shown in gold).*

Aquifer Contamination at the INEEL

Aquifer contamination at the INEEL exceeds the EPA's primary drinking water standards at five facilities: Test Area North, the Test Reactor Area, the Idaho Nuclear Technology and Engineering Center (INTEC), the Central Facilities Area, and the Radioactive Waste Management Complex (see Figures 10 and 11). The aquifer at other INEEL facilities meets drinking water standards.

In 1996, the DOE estimated that there was about 27,500 acre-feet of contaminated groundwater at the INEEL, about the capacity of Milner Reservoir near Twin Falls. (The eastern Snake River Plain Aquifer has about 200 million acre-feet of water considered economically useful to people.) Most of the contaminated groundwater is very dilute, though "hot spots" of concentrated contamination exist near several wells formerly used to inject wastewater into the aquifer.

Figure 10. *Artist's rendition of the INEEL showing approximate locations of aquifer contaminant plumes (in yellow) that exceed drinking water standards. These are at Test Area North, Test Reactor Area, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex.*



The water table beneath the INEEL increases in depth from north to south (vertical scale is exaggerated).

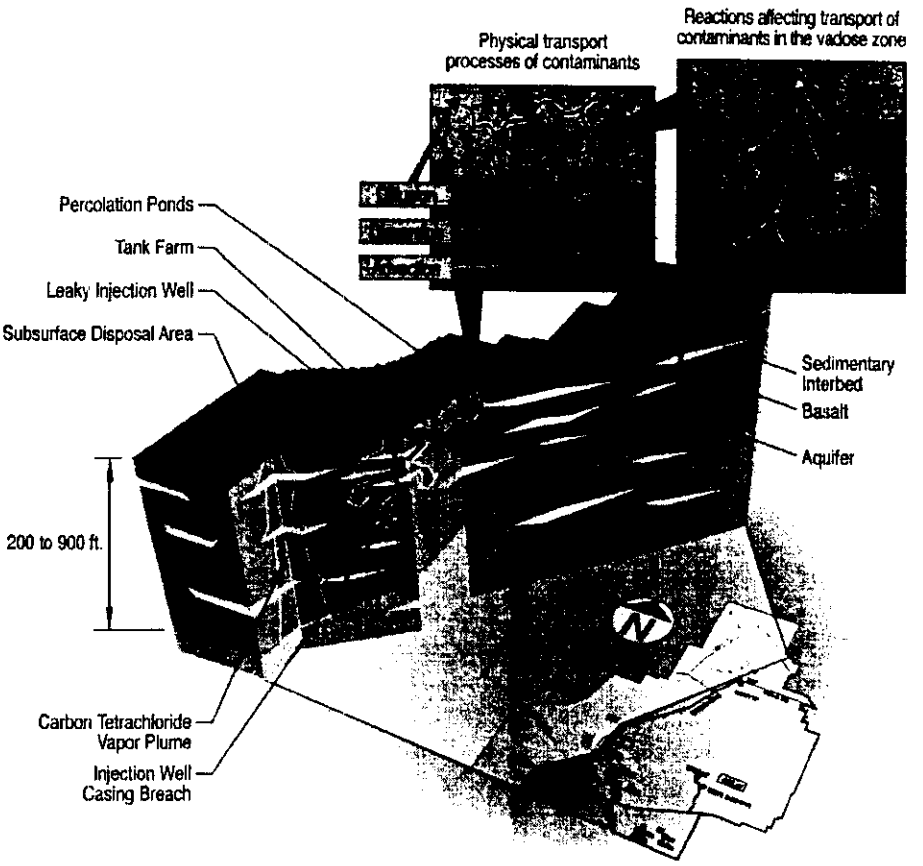


Figure 11. *A cross-section of the aquifer beneath the INEEL showing several sources of contamination, factors affecting contaminant mobility.*

Contaminated groundwater is also present in perched water zones and the vadose zone. Contaminants that have reached the aquifer at the INEEL have traveled with water from the surface downward, reached the aquifer directly in an injection well, or migrated downward as a vapor (see Figure 12).

Sources of Aquifer Contamination

Most contaminants are relatively immobile in rock and soil and need a driving agent to reach the aquifer. The driving agent at the INEEL is typically water, such as water discharge to ponds, surface water runoff, leaking facility water systems, or water injected into a well.

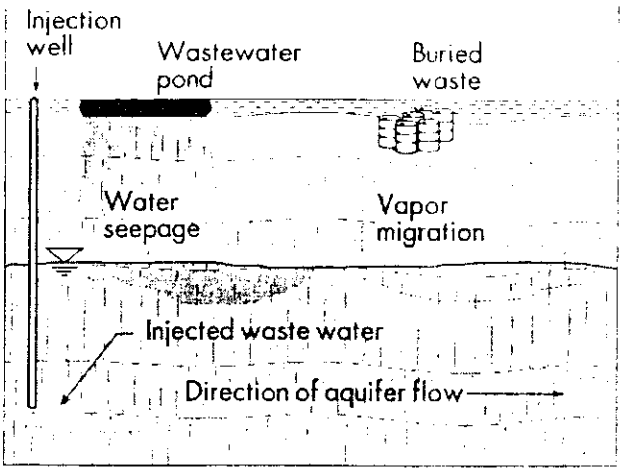


Figure 12. *Principal pathways of contaminant migration in the vadose zone at the INEEL.*

Because the INEEL is situated in a desert environment, and the aquifer is 200 to 1,000 feet beneath the surface, most aquifer contamination at the INEEL is associated with the continuous release of large quantities of contaminated wastewater to ponds and injection wells.

While buried waste and contaminated soil at the INEEL are a much less significant source of aquifer contamination than wells and wastewater, they have also resulted in some aquifer contamination that exceeds drinking water standards. For example, certain organic vapors that are highly mobile in rock and soil have leaked from buried waste at the Radioactive Waste Management Complex.

Significant quantities of contaminants at the INEEL are located in the vadose zone and in perched water. Most are expected to remain in the vadose zone once sources of water that mobilize contaminants are reduced or eliminated. Dikes and other control structures have been built at the INEEL to keep river water and precipitation runoff away from areas where this water could mobilize vadose zone contaminants. ❐

Aquifer Cleanup at the INEEL

Aquifer cleanup at the INEEL is driven by the potential risk to people who might drink groundwater drawn from the aquifer beneath or downgradient of the INEEL now and in the future. For the next 100 years, it is assumed that institutional controls, such as land-use restrictions and fences, will protect INEEL personnel and prevent potential future residents from exposure to contaminated water. During this 100-year period, if monitoring and modeling indicate that natural processes will result in aquifer contaminants diminishing to concentrations that meet drinking water standards, no cleanup action is required other than continued monitoring, environmental review, and institutional controls. However, if aquifer contaminants are predicted to persist at concentrations exceeding drinking water standards beyond 100 years, cleanup actions must be undertaken. (Natural processes that can reduce contaminant concentrations include biological, physical, and chemical processes which break down contaminants, and dilution and dispersion.)

Contaminated groundwater has not spread – nor is it projected to spread because of ongoing cleanup work – in concentrations sufficient to pose a risk to water users outside the INEEL's boundaries. However, at several locations within the INEEL's boundaries, contaminated groundwater would pose a risk to current and future water users, if it were consumed as the only source of drinking water.

Wastewater is still disposed of at the INEEL using sewage drainfields and disposal ponds. However, many older disposal ponds have been replaced with lined evaporation ponds and wastewater currently discharged to the environment at the INEEL does not carry contaminants in concentrations that pose a risk. Wastewater disposal at the INEEL is now closely monitored by the U.S. Department of Energy, the Environmental Protection Agency, and the state of Idaho Division of Environmental Quality in compliance with laws to ensure new aquifer contamination does not occur.

Table 1 summarizes the types and sources of aquifer contaminants at each INEEL facility. Tables 2 through 4 detail the characteristics of these contaminants, their breakdown rates in the environment, human exposure pathways, and potential human health risks. ❐

***Table 1.** Types and sources of aquifer contaminants exceeding safe drinking water standards at the INEEL, by facility.*

Test Area North

The organic chemicals tetrachloroethene (PCE), trichloroethene (TCE), and the radionuclides cesium-137, strontium-90, and tritium, were injected into the aquifer in a well. A breakdown product of PCE and TCE, cis- and trans-1,2-dichloroethene (DCE), is also present in the aquifer.

Test Reactor Area

The inorganic chemical chromium and the radionuclide tritium were injected into the aquifer in wells. Radionuclides also seeped into the aquifer from water disposal ponds.

Idaho Nuclear Technology and Engineering Center

The radionuclides iodine-129, strontium-90, and tritium were injected into the aquifer in a well. Radionuclides also leached into the aquifer from contaminated perched water zones and soils.

Central Facilities Area

The inorganic chemical nitrate originated at sewage treatment plants.

Power Burst Facility/Auxiliary Reactor Area

The aquifer at this area meets safe drinking water standards.

Experimental Breeder Reactor-I/ Boiling Water Reactor Experiment

The aquifer at this area meets safe drinking water standards.

Radioactive Waste Management Complex

The organic chemical carbon tetrachloride and the radionuclide strontium-90 migrated into the aquifer from buried waste.

Naval Reactor Facility

The aquifer at this area meets safe drinking water standards.

Argonne National Laboratory–West

The aquifer at this area meets safe drinking water standards.

Table 2. *Organic chemicals present in the aquifer at the INEEL at levels exceeding their Maximum Contaminant Level (MCL), in parts per billion (ppb). Characteristics listed are common uses, environmental transport characteristics, breakdown rates in the environment, human exposure pathways, and potential to cause human health risks at levels above MCL.*

Carbon Tetrachloride (CCl_4)				**MCL: 5 ppb**
Used as metal degreaser, cleaning agent, industrial solvent	Evaporates rapidly; highly mobile in soil; very slightly soluble in water	Breaks down extremely slowly in air, soil, and groundwater; half-life in groundwater is about 7,000 years	Exposure by breathing vapor, drinking contaminated water, or skin absorption	Potential to cause liver and central nervous system damage, and liver cancer at levels above MCL†
Cis- and Trans- 1,2-Dichloroethene (1,2-Dichloroethylene, DCE)				**MCL: 70 ppb for cis-, 100 ppb for trans-**
Used as industrial solvent; breakdown product of trichloroethene and tetrachloroethene	Evaporates moderately fast; highly mobile in soil; slightly soluble in water	Breaks down very slowly in air, soil, and groundwater	Exposure by breathing vapor or drinking contaminated water	Potential to cause liver, circulatory, and central nervous system damage at levels above MCL†*
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)				**MCL: 5 ppb**
Used as metal degreaser, cleaning agent	Evaporates rapidly; low to medium mobility in soils; adsorbs poorly to soils; very slightly soluble in water	Breaks down rapidly in air, slowly in soil and groundwater; half-life in groundwater is about 9 months	Exposure by breathing vapor or drinking contaminated water	Potential to cause liver, kidney and central nervous system damage, and cancer at levels above MCL†
Trichloroethene (Trichloroethylene, TCE)				**MCL: 5 ppb**
Used as metal degreaser	Evaporates rapidly; highly mobile in soil; binds poorly to soil; very slightly soluble in water	Breaks down rapidly in air, slowly in soil and groundwater	Exposure by breathing vapor or drinking contaminated water	Potential to cause liver damage and liver cancer at levels above MCL†

† No data on potential to cause birth defects.
* No data on potential to cause cancer.

Source: Environmental Protection Agency, Agency for Toxic Substances and Disease Registry.

Some Facts About Organic Chemicals

Organic chemicals are any chemical that contains carbon. They are called organic because all known life forms are based on carbon-containing chemicals. Common organic chemicals include gasoline, paint thinner, and alcohol.

Many organic chemicals are readily absorbed by internal body tissues. Because the liver is the human body's major site of chemical breakdown, some organic chemicals can cause serious liver damage and increase the likelihood of liver cancer.

Many organic chemicals are practically insoluble in water and will either float or sink in water depending upon their density relative to water. For example, gasoline floats on the surface of water in a thin film, whereas trichloroethene sinks. Because trichloroethene sinks and does not dissolve in water, it is referred to as a dense, non-aqueous phase liquid, or DNAPL, which is often pronounced "Dee-napple."

Table 3. *Inorganic chemicals present in the aquifer at the INEEL at levels exceeding their Maximum Contaminant Level (MCL), in parts per billion (ppb). Characteristics listed are common uses, environmental transport characteristics, human exposure pathways, and potential to cause human health risks at levels above MCL.*

Chromium (Hexavalent Chromium, Chromium-VI)			**MCL: 100 ppb**
Used as anti-corrosive additive to cooling water; many plating and alloying uses	Dust settles rapidly from air; very low mobility in soils, some forms bind strongly to soil; solubility varies depending on form	Exposure by breathing dust, eating contaminated food, or drinking contaminated water	Potential to cause liver, kidney, circulatory, nervous system, and skin damage at levels above MCL; probable cause of lung cancer when breathed as dust†
Lead			**MCL: 0 ppb; Cleanup action must take place at levels above 10 ppb**
Used in many industrial, commercial, and nuclear research processes and products	Dust settles from air; relatively immobile in soils; can transform in the environment to soluble forms	Exposure by breathing dust, eating contaminated food, or drinking contaminated water	Potential to cause mental deficits, circulatory, and kidney damage, and cancer at levels above MCL; extremely high potential to cause circulatory and mental deficits both pre- and post-natal
Nitrate and Nitrite			**MCL: 10,000 ppb**
Used as a fertilizer; common industrial byproduct and constituent of animal waste	Does not evaporate; highly mobile in soil; highly soluble in water	Exposure by drinking contaminated water	Interferes with infants' ability to carry oxygen in the blood (blue-baby syndrome) and can lead to infant death if not treated; potential to cause damage to the spleen at levels above MCL*

† No data on potential to cause cancer or birth defects when ingested in food or water.
* No data on potential to cause cancer.

Source: Environmental Protection Agency, Agency for Toxic Substances and Disease Registry.

Some Facts About Inorganic Chemicals

Inorganic chemicals include metals and nitrogen-containing compounds such as nitrate. Inorganic chemicals are more difficult to characterize than organic chemicals because most readily form compounds with oxygen and other common elements.

While many metals are essential to life, practically all are toxic in excessive quantities, and some such as mercury and lead are toxic in very small quantities. Some forms of metals are extremely stable in the environment and retain the potential to cause harm essentially forever.

Nitrate is a categorical term for nitrate and nitrite, which are simple compounds of oxygen and nitrogen. Nitrates are a byproduct of many industrial processes, a constituent of animal waste, and a common fertilizer. Nitrates are also the end product of breakdown pathways for many nitrogen-containing chemicals.

Metals in the environment are commonly absorbed and concentrated by plants and animals. This can be dangerous to humans if they eat the plants and animals. On the other hand, this characteristic is useful to some environmental restoration projects. After plants absorb metals that contaminate soils, the plants are harvested and safely disposed of, removing the absorbed metals from the environment.

Table 4. *Radionuclides present in the aquifer at the INEEL at levels exceeding their Maximum Contaminant Level (MCL), in picocuries per liter (pCi/L), a measure of radioactivity. Characteristics listed are half-lives, environmental transport characteristics, and specific human health risks.*

Cesium-137			**MCL: 119 pCi/L (proposed)**
	Half-life is 30.17 years	Binds strongly to rock and soil	
Iodine-129			**MCL: 1 pCi/L (proposed)**
	Half-life is 17 million years	Very slightly soluble in water, highly soluble in organic solvents	Concentrates in the thyroid
Strontium-90			**MCL: 8 pCi/L**
	Half-life is 29.00 years	Soluble in water and can be transported great distances	Concentrates in bones
Tritium (H-3)			**MCL: 20,000 pCi/L**
	Half-life is 12.32 years	Most is found as a component of water	

Source: Environmental Protection Agency, Agency for Toxic Substances and Disease Registry.

Some Facts About Radionuclides

Radionuclides are radioactive forms of elements, e.g., iodine-129 is a radioactive form of iodine. Tritium is a radioactive form of hydrogen that is usually found as a component of water (water is composed of hydrogen and oxygen).

Radionuclides decay (emit radioactivity) at predictable rates called half-lives. A half-life is the time it takes for one-half of the atoms in a quantity of a radionuclide to decay. Starting with the original quantity, 50 percent of the atoms have decayed after the first half-life, 75 percent after the second half-life, and so forth. After 7 half-lives, less than 1 percent of the radionuclide remains in its original form, and the rest has decayed either into another radionuclide or a non-radioactive substance.

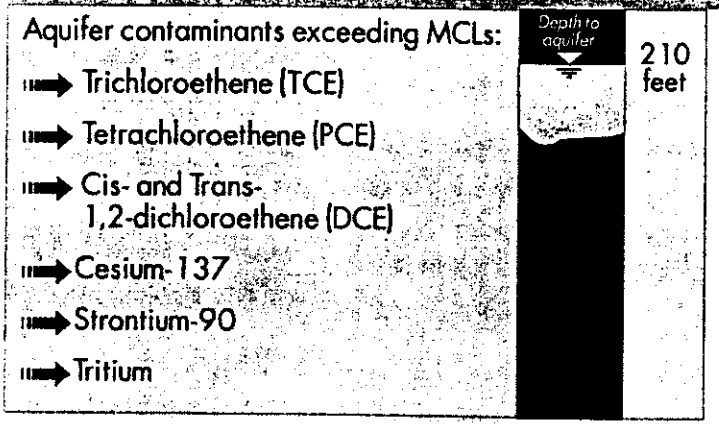
Radionuclides can be ingested as inhaled dust, or in food and water. Low doses of radiation, such as what might be found in contaminated drinking water, can damage the genetic material in cells and lead to cancer.

Most radionuclides are not very mobile in soils and rock, though they can be transported significant distances by water and other liquids. In the environment, most radionuclides quickly form compounds with oxygen and other common elements.

Water containing tritium is almost identical to ordinary water except it is radioactive and slightly heavier. There is no practical cleanup method that can separate tritium-containing water from ordinary water. After 86 years, less than 1 percent of the original radioactivity in a quantity of tritium-containing water will remain.

Cesium-137 and strontium-90 are often found in equal proportion close to sources of contamination at nuclear facilities. Cesium-137 binds strongly to rock beneath the INEEL, while strontium-90 does not. As a result, the proportion at which the two radionuclides are found rapidly rises in favor of strontium-90 as the distance increases from the source of contamination. This characteristic is useful in determining the source of contamination.

Test Area North



Test Area North was established in 1951 to support the Aircraft Nuclear Propulsion Program. Later the area was expanded to support other reactor testing programs, nuclear fuel tests, and manufacturing operations. It has highly developed support facilities to manufacture, manipulate, and handle radioactive components, including hot cells for handling fuel units, and machine and maintenance shops. Test Area North currently supports spent nuclear fuel inspection and storage, and the Specific Manufacturing Facility, which manufactures armor for military vehicles.

The depth to the water table at Test Area North varies from 200 to 250 feet. The water table is closer to the surface at this area than at any other INEEL facility. The aquifer thickness is at least 900 feet. A relatively impermeable sedimentary interbed locally isolates the upper 200 to 250 feet of the aquifer. The local direction of aquifer flow is generally to the south-southeast. Aquifer flow velocity at Test Area North is about 0.5 feet per day, much slower than average for the INEEL. The aquifer is locally recharged, to a minor degree, by Birch Creek and the Technical Support Facility (TSF) waste disposal pond. The only known perched water zone is about 45 feet beneath the disposal pond. The perched water, which is not known to have significant contamination, is small in volume and area and is expected to dissipate once use of the pond is discontinued.

Types and Sources of Aquifer Contaminants

Aquifer contaminants at Test Area North whose concentrations consistently exceed drinking water standards are the organic chemicals trichloroethene (TCE), cis- and trans-1,2-dichloroethene (DCE), and tetrachloroethene (PCE); and the radionuclides cesium-137, strontium-90, and tritium.

The primary source of groundwater contamination at Test Area North was injection well TSF-05, located near the Technical Support Facility (TSF). The well was drilled to a depth of 310 feet, and is open to the aquifer 180 to 244 feet and 269 to 305 feet below the surface. The well was used for wastewater disposal from 1953 to 1972, then replaced by the TSF waste disposal pond.

Other injection wells and disposal ponds at Test Area North are not believed to have contributed significant amounts of contamination to groundwater. While the TSF waste disposal pond received contaminated wastewater after use of injection well TSF-05 ceased, investigations found that significant quantities of contaminants have not penetrated more than 11 feet into the soils beneath the pond.

Injection well TSF-05 received waste from machining and maintenance operations, process wastewater, sanitary sewage, and low-level radioactive waste streams. Most of the contaminants are located at a small "hot spot" in the immediate vicinity of the injection well where they greatly exceed drinking water standards (see Figures 13a and 13b).

Cleanup Activities

The contaminant in the aquifer at Test Area North that poses the greatest risk to human health is TCE. Methods that remove TCE from the aquifer will also remove the chemically similar PCE and DCE. TCE will persist in the aquifer above drinking water standards for more than 100 years unless cleanup work reduces its concentration, particularly in the vicinity of the hot spot.

Cesium-137, strontium-90, and tritium are present in low concentrations in the aquifer at Test Area North, and have short half-lives. Their concentration in the aquifer is expected to naturally diminish to meet drinking water standards within 100 years.

In 1990, INEEL personnel removed sludge, containing very high concentrations of many contaminants, that had built up in the bottom 55 feet of injection well TSF-05. A pump-and-treat system began operating at injection well

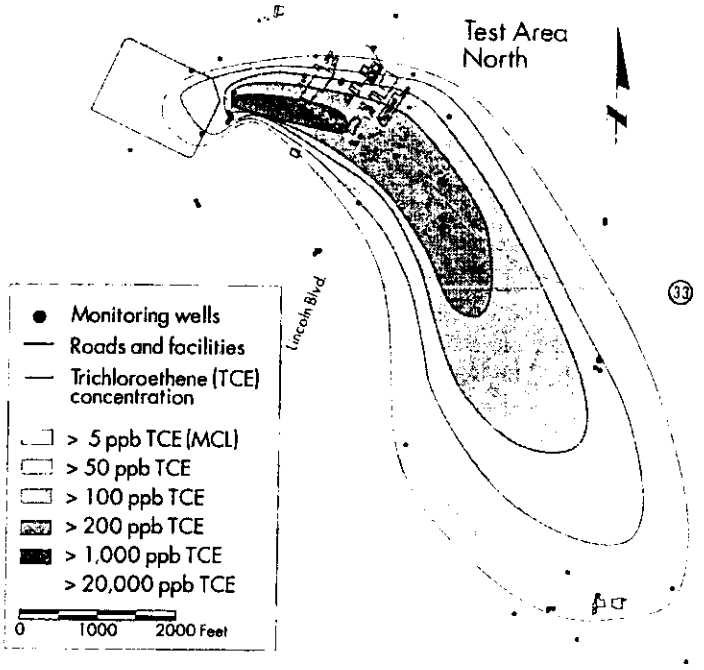


Figure 13a. *Trichloroethene (TCE) is the aquifer contaminant that poses the greatest risk to human health at Test Area North. The map illustrates the approximate extent of its plume.*

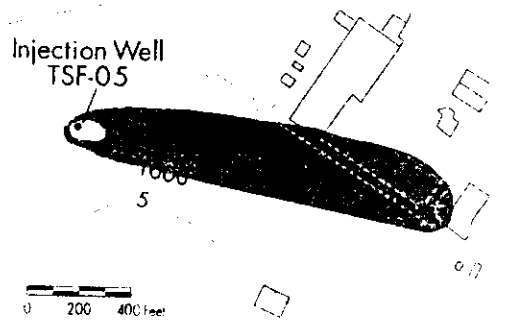


Figure 13b. *Enlargement of trichloroethene hot spot and medial contamination zone at Test Area North.*

TSF-05 in February 1994. The objectives of this interim cleanup action were to remove contaminated groundwater from the hot spot, treat the water to remove organic chemicals and radionuclides, and measure contaminant distributions. Water treated in the system was initially discharged to the TSF waste disposal pond.

The pump-and-treat system at the hot spot was built and operated as designed. However, it was not effective in reducing contaminant levels in the aquifer to Maximum Contaminant Levels (MCLs) because of unexpectedly high concentrations of contaminants in the groundwater and operational limitations of the treatment system. Modifications were subsequently made to the pump-and-treat system so that it would operate on a continuous basis to provide hydraulic containment of the hot spot and to reduce contaminant concentrations, although not to MCLs. While treated water was much cleaner than untreated water, the pump-and-treat system could not make it clean enough to discharge to the TSF waste disposal pond. It was decided to reinject treated water into the aquifer rather than continue discharging it to the pond, which would have created a new source of contamination, primarily radionuclide, in soils beneath the pond.

To continue treatment and containment of the hot spot at injection well TSF-05, the modified pump-and-treat system was incorporated into a final cleanup action in August 1995. The final cleanup action included plans to evaluate five alternate cleanup technologies because of the pump-and-treat system's limitations. After laboratory evaluation, two of these technologies were eliminated from further consideration.

In November 1997, radionuclide removal was eliminated as a component of the hot spot pump-and-treat system because laboratory tests showed that existing technologies would not cost-effectively accomplish cleanup objectives. At the same time, it was planned to install a new medial zone pump-and-treat system downgradient of the hot spot. A draft design for the new pump-and-treat system has been prepared, and the system is scheduled to become operational in 2001.

Also in November 1997, it was decided to extend the cleanup schedule to perform field evaluations of the three

alternate aquifer cleanup technologies. During the field evaluations, hot spot containment is provided by the existing hot spot pump-and-treat system, or an equivalent and more cost-effective pump-and-treat system.

Alternate Cleanup Technologies

Three alternate technologies for aquifer cleanup at Test Area North were selected for field evaluation: in situ chemical oxidation, natural attenuation, and in situ bioremediation. All are in situ (in place) cleanup technologies using engineered systems or natural processes to reduce contaminant concentrations within the aquifer itself, rather than first removing water from the aquifer and then treating it to reduce contaminant concentrations (ex situ treatment). In situ contaminant treatment is potentially advantageous over ex situ treatment because some contaminants, such as TCE, tend to remain within the aquifer when water is pumped out, reducing the efficiency of the ex situ treatment system. However, in situ chemical oxidation was later screened out during treatability studies due to the successful field evaluation of bioremediation.

Natural Attenuation

Natural attenuation includes a variety of physical, chemical, and biological processes that reduce the mass, toxicity, mobility, volume, or concentration of contaminants, without human intervention. Dispersion and biodegradation are believed to be the most important natural attenuation mechanisms at Test Area North.

Bacteria that live in the subsurface at the INEEL may naturally break down TCE and similar organic chemicals, though at a very slow rate. However, the mechanism of natural attenuation is not completely understood. Through natural attenuation, TCE in groundwater at Test Area North appears to have a half-life of about 20 years. (While the term half-life is generally associated with radionuclides, it applies to any chemical compound that is unstable. Radionuclide half-lives are predictable, whereas organic chemical half-lives depend upon environmental conditions.)

Natural attenuation was evaluated at field scale with the goals of better understanding the mechanism of natural attenuation and more accurately determining the rate of TCE breakdown. Based on the positive results of the evaluation, natural attenuation has been selected as the preferred treatment alternative for the distal zone. Given the 100-year time constraint for the cleanup action, natural attenuation is expected to be effective at Test Area North in the distal portion of the TCE plume, where concentrations are less than 1,000 ppb. Monitoring will be conducted to ensure its effectiveness.

In Situ Bioremediation

In situ bioremediation is similar to natural attenuation, except the bacteria are actively stimulated to significantly increase the rate at which they break down organic chemicals. The bacteria are stimulated when large quantities of a nutrient are artificially provided.

Organisms process nutrients into energy through a series of chemical reactions. These reactions require chemicals, such as oxygen, to take place. Most organisms prefer to use oxygen to process food into energy. However, bacteria that live in oxygen-poor environments are capable of using other chemicals instead of oxygen when they process food.

When bacteria that live deep underground are presented with large quantities of a nutrient, they multiply and quickly consume all the oxygen in the groundwater. After the oxygen is gone, anaerobic bacteria consume other compounds such as nitrate, sulfate, and manganese and iron oxides in lieu of oxygen. To continue living when these compounds are depleted, the bacteria will turn to organic chemicals such as TCE. When this happens, the bacteria break down TCE and other hazardous organic chemicals to non-toxic substances.

Field evaluation of bioremediation for hot spot cleanup began in November 1998, using lactate (a byproduct of fermented sugars commonly used in the medical and pharmaceutical industries) as the artificially provided nutrient (see Figure 14). INEEL scientists and engineers chose lactate because the bacteria readily consume it, is inexpensive, non-hazardous to the environment, and highly soluble in water. Lactate's solubility allows it to diffuse into the aquifer, reaching the bacteria and the TCE beyond the injection site itself. This gives bioremediation a significant advantage over ex situ cleanup methods.

Initial results of bioremediation at Test Area North have been extremely promising. TCE concentrations in monitoring wells near the hot spot decreased significantly, and ethene (the breakdown product for TCE)

concentrations rose (see Figure 15). In fact, TCE concentrations are now undectectable at all monitoring points within 100 feet downgradient of injection well TSF-05. Concentrations of carbon dioxide, an indicator of increased biological activity, also rose, indicating the desired biochemical reactions are going to completion. A field evaluation of bioremediation was conducted at Test Area North through early 2000 to determine the rate at which bioremediation breaks down organic chemicals within the aquifer, and to evaluate its effectiveness on the hot spot. Bioremediation was determined to be successful and is being chosen as the preferred hot spot cleanup remedy. Pump-and-treat will continue to be used in the medial zone. Both pump-and-treat in the medial zone and monitored natural attenuation of the distal zone are being chosen as the preferred cleanup remedies for those zones. ❐

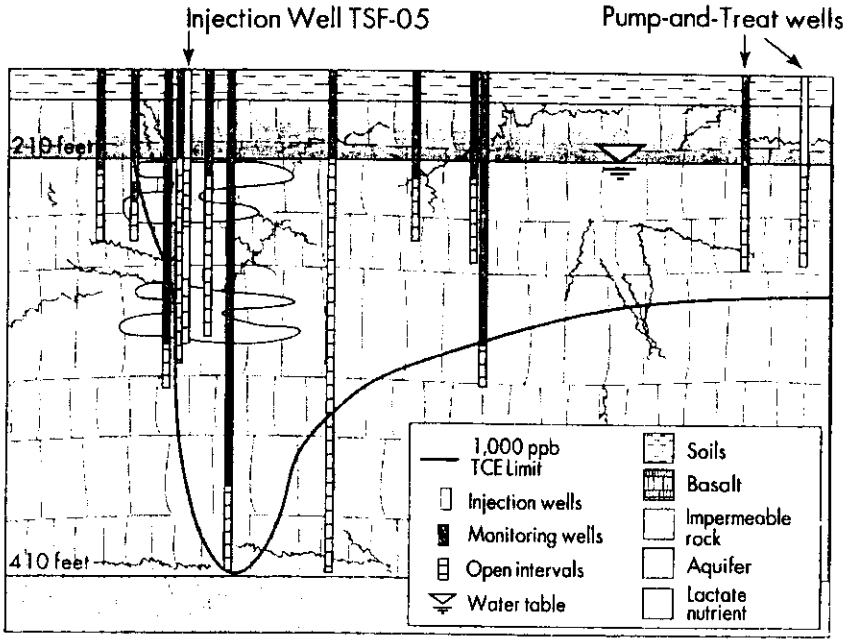


Figure 14. *Cross-section showing trichloroethene (TCE) hot spot at Test Area North and lactate diffusion (not to scale).*

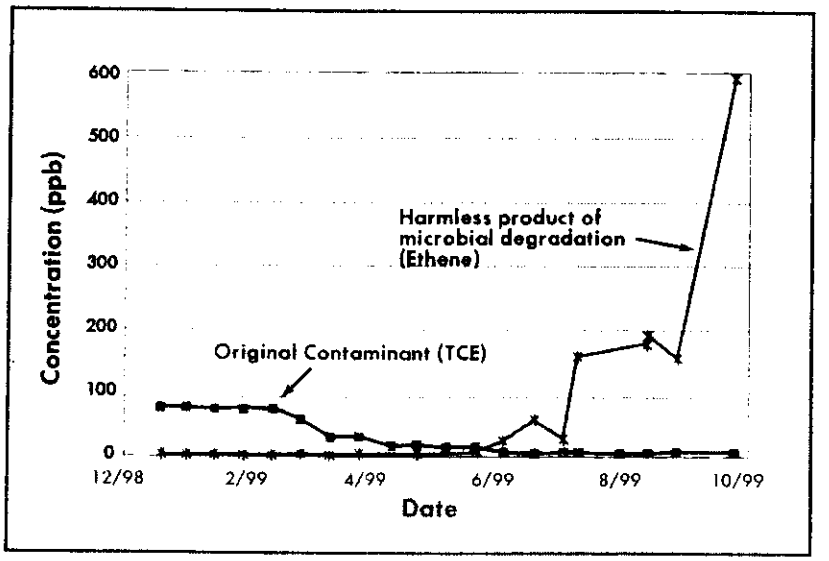
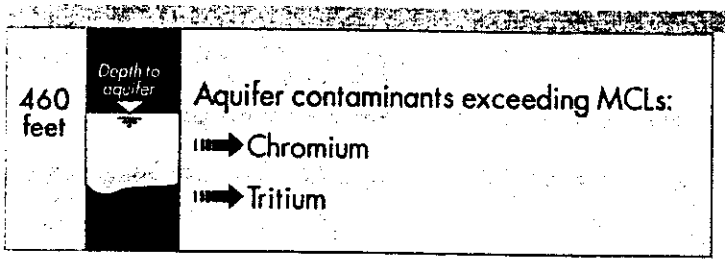
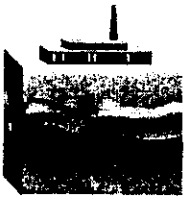


Figure 15. *Initial results of bioremediation in the aquifer at Test Area North indicate a significant drop in TCE levels.*

Test Reactor Area





The Test Reactor Area was established in 1952 to study the effects of radiation on materials, fuels, and equipment. Three major and four small reactors were built at the area, with support facilities. The Materials Test Reactor operated from 1952 to 1970 and the Engineering Test Reactor operated from 1957 to 1981. The Advanced Test Reactor, built in 1967, is currently the only operational reactor at the INEEL. It produces radionuclides for medicine and industry in addition to its research role.

The depth to the water table at the Test Reactor Area is approximately 450 feet. The thickness of the active portion of the aquifer is about 250 feet. The local direction of aquifer flow is to the south-southwest. Aquifer flow velocity ranges from 5 to 20 feet per day. The aquifer is locally recharged by the Big Lost River and by clean water that enters the subsurface at the rate of approximately 300 gallons per hour from one disposal pond still being used.

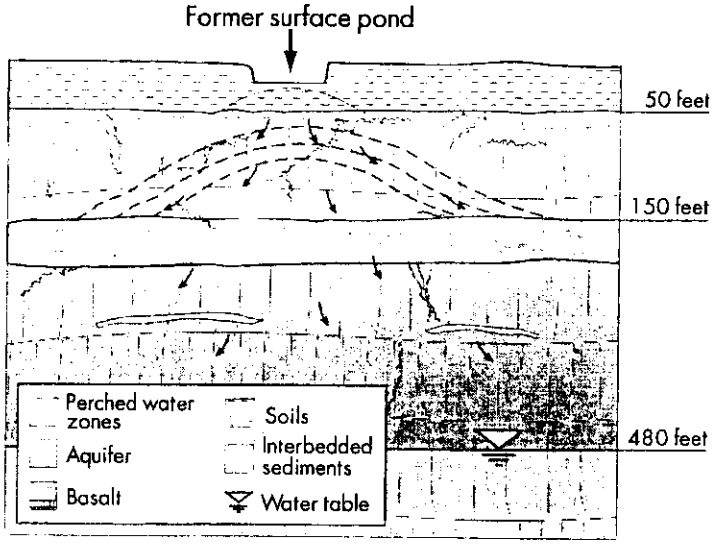


Figure 16. *Conceptual cross-section of perched water zones beneath the Test Reactor Area showing general direction of water seepage. Dashed lines in deep perched water zone indicate how zone will shrink after pond is removed.*

There are perched water zones at two depths beneath the Test Reactor Area (see Figure 16). The shallow perched water zone is approximately 50 feet below the surface, and the deep perched water zone is approximately 150 feet below the surface. The shallow zone rapidly leaks to the deep zone. The deep zone currently occupies an area of about 3,000 feet by 6,000 feet and contains an estimated 4,000 acre-feet of water. The perched water zones are the result of seepage from waste ponds at the Test Reactor Area (from the late 1950s until recently, approximately 613 acre-feet of water were discharged annually to the ponds). The Big Lost River may also contribute to the perched water.

Types and Sources of Groundwater Contaminants

Contaminated groundwater at the Test Reactor Area is located in the shallow and deep perched water zones and in the aquifer. Aquifer contaminants whose concentrations consistently exceed drinking water standards are the inorganic chemical chromium and the radionuclide tritium.

Injection well TRA-05 was used to dispose of approximately 12,000 acre-feet of chromium- and tritium-contaminated wastewater between 1964 and 1982. The well is 1,271 feet deep and perforated at intervals beginning 510 feet below the surface. Approximately 31,000 pounds of chromium were injected into the aquifer until 1972, when the Test Reactor Area ceased using chromium as a corrosion inhibitor in reactor cooling systems. A 90-foot-deep monitoring well, USGS-53, was used intermittently from 1960 to 1964 to inject an estimated 675 acre-feet of wastewater to the perched water system. It is not believed this wastewater contained significant quantities of chromium and radionuclides. Another source of aquifer contamination is the warm waste pond, whose three cells were constructed in 1952, 1957 and 1964, and used until 1993. The warm waste pond received reactor cooling water containing inorganic chemicals and radionuclides.

In addition to chromium and tritium, the inorganic chemicals arsenic, beryllium, cadmium, lead, and nitrate, and the radionuclides cobalt-60 and strontium-90, have been detected in the deep perched water zone in concentrations that exceed drinking water standards. Nitrate and the organic chemical trichloroethene have

been detected inconsistently in the aquifer at levels above drinking water standards.

Cleanup Activities

In 1992, it was decided that drinking water standards for the aquifer at the Test Reactor Area could be met by drying up the deep perched water zone, thereby leaving contaminants in the vadose zone and preventing them from reaching the aquifer. Assuming the contaminants remained in the vadose zone, fate and transport modeling predicted that chromium concentrations in the aquifer would meet drinking water standards in 2016 (through dilution and dispersion), and tritium concentrations in the aquifer would meet drinking water standards in 2004 (through radioactive decay, dilution, and dispersion). If contaminant concentrations in the aquifer continue to decrease at the desired rate, no cleanup action will be required other than continued monitoring of groundwater, periodic environmental review, and institutional controls.

To dry up the deep perched water zone, it was decided to discontinue the use of unlined ponds (see Figure 17). The warm waste pond, the principal source of contaminated water to the deep perched water zone, was replaced with a lined pond in 1993. The cold waste pond, the source of about 85 percent of total water to the deep perched water zone after 1982 (when it began accepting water that previously went to injection well TRA-05), will be replaced in the future with a lined pond. At present, the cold waste pond receives approximately 484 acre-feet of water annually. The chemical waste pond, sewage leach pond, and retention basin have been taken out of service, and capped with engineered covers.

From 1993 to 1996, the deep perched water zone decreased in volume approximately 19 percent, due primarily to disuse of the cold waste pond in 1993. Between 1996 and 1998, water levels in monitoring wells in the deep perched water zone have declined slightly in two cases and increased slightly in two others, indicating that the volume of the deep perched water zone is not decreasing as quickly as before. Chromium and tritium concentrations in the aquifer are decreasing, but at a slower rate than predicted, principally because the deep perched water zone is not decreasing in volume as rapidly as anticipated. ❐

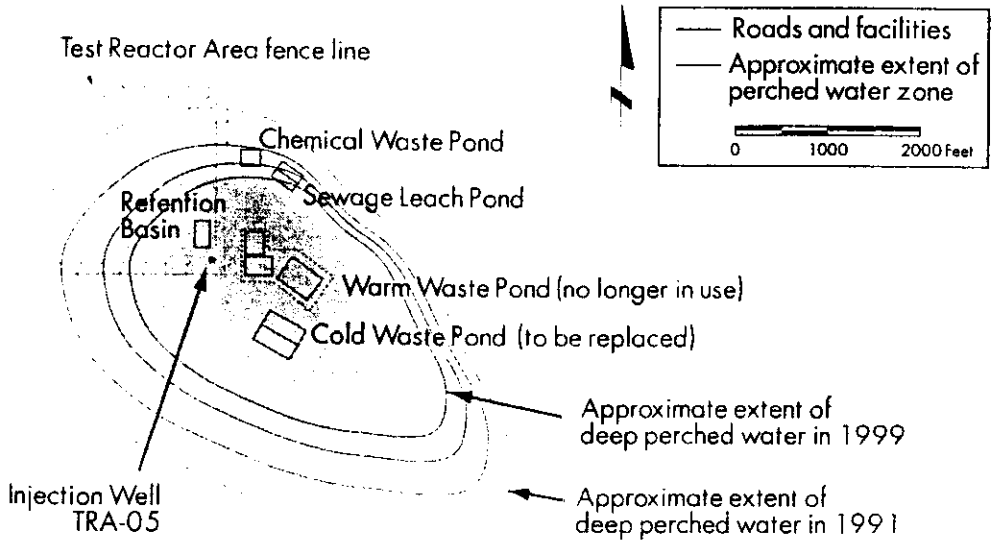
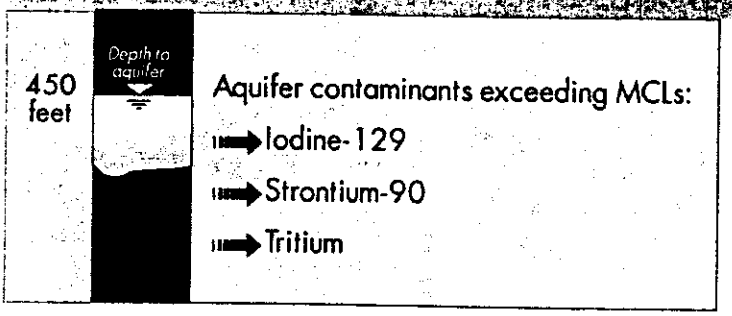
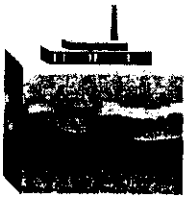


Figure 17. *The deep perched water zone at the Test Reactor Area has diminished in volume following the elimination of water sources.*

Idaho Nuclear Engineering and Technology Center (INTEC)





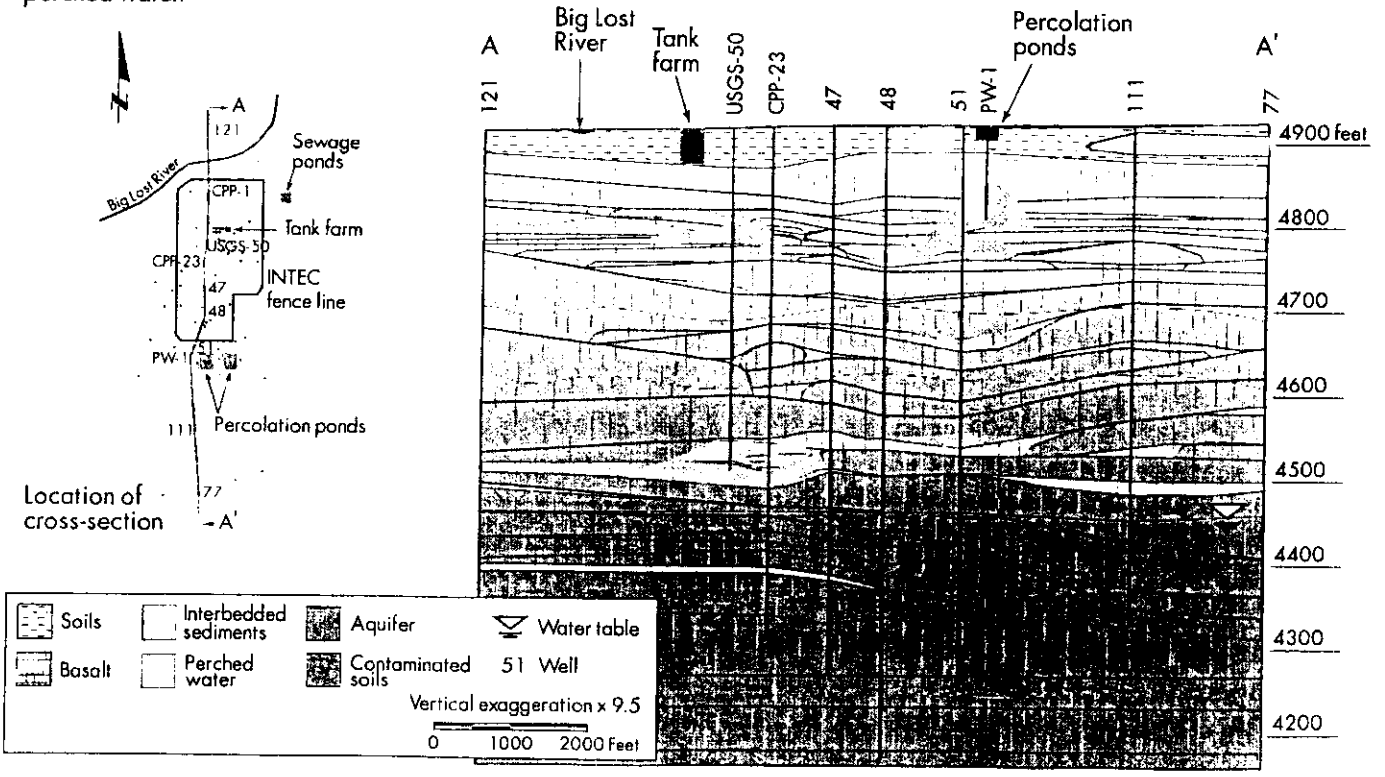
The Idaho Nuclear Technology and Engineering Center (INTEC), originally known as the Idaho Chemical Processing Plant, was constructed in 1952 to reprocess spent nuclear fuel from naval and research reactors. Reprocessing at the INTEC recovered enriched uranium by dissolving spent nuclear fuel in concentrated solutions of nitric acid and extracting uranium from the solutions. The resulting liquid waste is classified as high-level waste and is extremely radioactive and corrosive. The INTEC began calcining (evaporating and oxidizing) its liquid waste into a granular form in 1963 to reduce waste volume and simplify its storage.

Spent fuel reprocessing ended at the INTEC in 1992. Currently, the INTEC stores spent nuclear fuel and calcines remaining sodium-bearing radioactive waste. The plant's major facilities are spent fuel storage pools, the waste calciner, and a tank farm that stores liquid waste prior to calcining. The tank farm has a 3,475,200 gallon capacity. There are currently about 1.4 million gallons of sodium-bearing waste awaiting calcining. This waste is scheduled to be calcined by 2012. Support facilities include miscellaneous chemical storage and processing facilities, wastewater disposal ponds, offices, maintenance shops, and laboratories.

The depth to the water table at the INTEC is approximately 450 feet. The local direction of aquifer flow is generally to the south. Aquifer flow velocity averages 10 feet per day. The aquifer is locally recharged by the Big Lost River and various INTEC sources.

There are several perched water zones beneath the INTEC, separated both in area and in depth (see Figure 18). The sources of water for the perched water zones and their estimated amount of contribution are the INTEC's two percolation ponds (70.4 percent), the Big Lost River (20.7 percent), precipitation (6.6 percent), the INTEC's sewage lagoons (1.5 percent), and other artificial sources (less than 1 percent). The southern perched water zones receive most of their recharge from the percolation ponds, and the northern zones from multiple sources.

Figure 18. *Cross-section of the vadose zone and aquifer at the INTEC showing sources and approximate extent of perched water.*



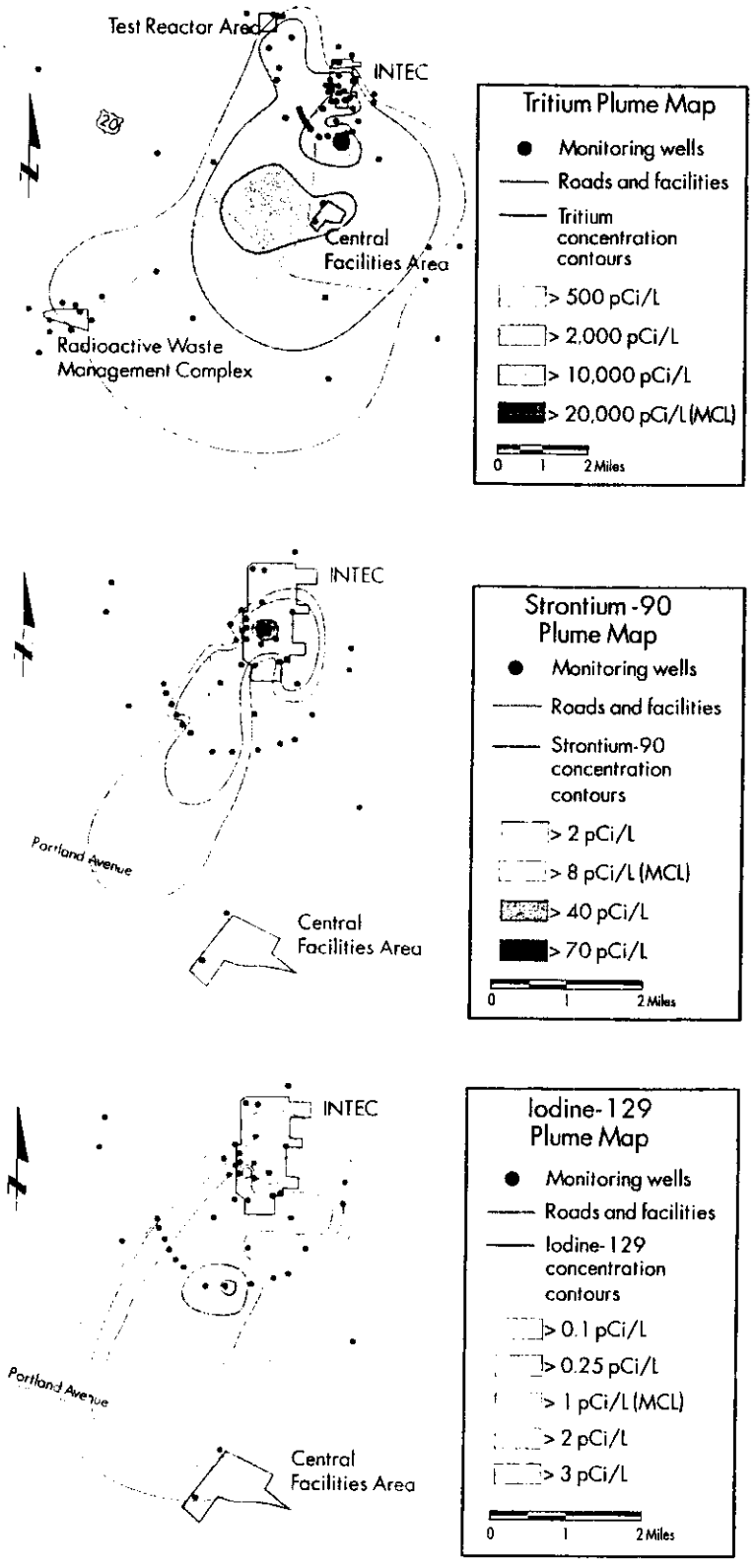


Figure 19. *Three aquifer contaminants at the INTEC exceed drinking water standards: tritium, strontium-90, and iodine-129. The maps illustrate the approximate extent of their aquifer plumes.*

Types and Sources of Groundwater Contaminants

Contaminated groundwater at the INTEC is located in perched water zones and the aquifer. Aquifer contaminants at the INTEC whose concentrations consistently exceed drinking water standards are the radionuclides iodine-129, strontium-90, and tritium. The tritium plume from the Test Reactor Area, located upgradient of the INTEC, has merged with the tritium plume from the INTEC (see Figure 19). In addition, plutonium migrating from the vadose zone may pose a future risk to the aquifer.

The primary sources of aquifer contamination at the INTEC are injection well CPP-23 (now closed) and contaminated soils at the INTEC tank farm. The tank farm soils continue to contribute contaminants to the aquifer. The injection well delivered contaminants directly to the aquifer, whereas contaminants from the tank farm must travel downward through 450 feet of rock and soil before reaching the aquifer.

Injection well CPP-23 was drilled to a depth of 580 feet and is open to the aquifer through the bottom 130 feet. From 1952 to 1984, the INTEC annually discharged to CPP-23 an average of 933 acre-feet of plant wastewater, cooling water, and condensate. It was used intermittently from 1984 to 1989, when it was permanently closed by grouting. In 1971, an unlined portion of CPP-23 collapsed. While it was under repair, monitoring well USGS-50 was temporarily used in its place. Several years later, in 1982, an unlined portion of CPP-23 again collapsed. This time, the INTEC's percolation ponds were temporarily used during the repair period.

The principal contaminant injected into the aquifer was tritium, which accounted for nearly all of the radioactivity in the injection water. Other significant contaminants in the injection water were mercury and the radionuclides cesium-137, strontium-90, and plutonium. Until 1995, mercury exceeded drinking water standards in a hot spot in the immediate vicinity of the injection well, and has since declined below its MCL at the hot spot and elsewhere.

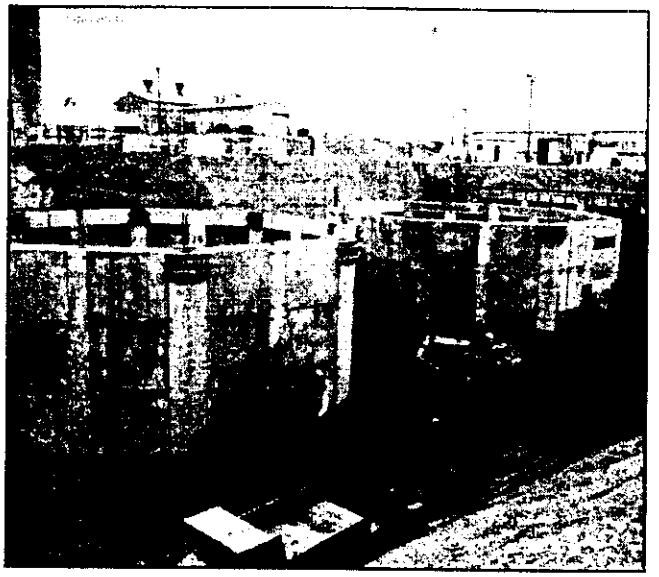


Figure 20. *The INTEC tank farm, shown under construction during the 1950s, is the principal source of contamination at the INTEC. The tanks themselves are not known to have leaked.*

Tank farm soils contain about 95 percent of the total radioactivity released to the environment at the INTEC to date. An estimated 146,000 cubic yards of soil at the tank farm have been contaminated by spills or leaks. More than 90 percent of the potential source of cesium-137 and strontium-90 in the aquifer at INTEC is believed to have its origin in tank farm soils. Tank farm soils contain significant quantities of long-lived radionuclides including europium, plutonium and uranium. The chemistry and mechanism of processes that affect plutonium mobility in tank farm soils and the underlying vadose zone are under investigation. These investigations will seek to determine the risk to the aquifer posed by the contaminated soils. Tank farm soils also contain large quantities of organic and inorganic chemicals.

None of the tanks at the tank farm are known to have leaked; contaminated soil has resulted from pipeline leaks and spills during liquid transfers. Precipitation is the primary source of water available to transport contaminants through the vadose zone at the tank farm. Planned and accidental releases of process liquids at the tank farm probably have totaled less than 100,000 gallons. Significant contamination is found at the soil/basalt interface approximately 45 feet beneath the surface. The tank farm is scheduled to operate until 2015.

Perched Water Contamination

Several areas of perched water at INTEC have contaminant concentrations greatly in excess of drinking water standards. In the northern perched water zone, strontium-90 was detected in 1991 in one monitoring well at a concentration 46 times the drinking water standard, and in another well at 4,600 times the drinking water standard. Cesium-137 has historically been detected at concentrations as high as 9 times its proposed drinking water standard of 119 pCi/L.

Some contamination in the perched water zones originated from the collapse of unlined portions of injection well CPP-23 in 1971 and 1982. When this occurred, wastewater discharged to the well flooded the vadose zone until the well collapses were discovered.

The primary source of water for the southern perched water zone are the two percolation ponds, constructed in 1984 and 1985 to replace the injection well. Water discharged to the ponds either evaporates or seeps into the aquifer. Since 1984, the ponds have received an average of about 1,800 acre-feet of wastewater per year. Wastewater discharged to the percolation ponds has included highly diluted inorganic chemicals and radionuclides. Based on observations of radionuclide transport times, wastewater travels from the percolation ponds to the aquifer in approximately 225 days.

Water from the southern perched water zone may be mobilizing vadose zone contaminants, including contaminants that originated at the tank farm. In addition, water currently discharged to the percolation ponds exceeds secondary drinking water levels for total dissolved solids (TDS) and chloride ion. (Chloride ion is one of the components of salt.)

The southern perched water zone is less contaminated than the northern zone. Nitrate has been detected in concentrations as high as 7 times its drinking water standard, and strontium-90 has been detected in one well at a concentration slightly exceeding its drinking water standard.

Cleanup Activities

If consumed, contaminated groundwater at the INTEC would pose a risk to human health. The contamination in the perched water zones does not pose a direct risk to

human health because it can not be produced from these zones in useful quantities. The perched water zones are expected to disappear or diminish within the 20 year period following the end of INTEC operation.

It is expected that natural attenuation, dispersion, and decay will probably be sufficient to reduce aquifer contamination at the INTEC to acceptable levels within 100 years. However, these natural mechanisms will be insufficient if contaminants continue to enter the aquifer at current rates. To reduce the amount of contaminants that enter the aquifer, it is proposed to leave contaminants in the vadose zone by reducing the amount of water that seeps into the ground at the tank farm, percolation ponds, and other INTEC sources.

At the tank farm, it is proposed to grade the land surface, direct runoff from buildings and paved areas away from contaminated soils, and discontinue lawn watering. Runoff control is predicted to reduce the rate of contamination migration to the northern perched water zone by approximately a factor of five.

At the percolation ponds, it is proposed to discontinue use of the existing percolation ponds, and construct a replacement water disposal system at a new location where seepage cannot recharge the existing perched water zone.

Other sources of perched water are the Big Lost River, the INTEC's sewage treatment ponds, and miscellaneous water leaks at the INTEC. It may be necessary to line the Big Lost River in the vicinity of the INTEC, relocate the sewage ponds, and repair leaking fire water lines.

It is uncertain whether the proposed measures will sufficiently reduce the rate of contaminant entry from the vadose zone to the aquifer. This uncertainty reflects the very large quantity of long-lived contaminants in the perched water and vadose zones, an incomplete understanding of contaminant transport in the vadose zone, the amount and sources of water available for contaminant transport, and water's influence on contaminant migration.

Some fate and transport models of plutonium in the vadose zone predict that plutonium may someday enter the aquifer in quantities exceeding drinking water standards. However, there is considerable uncertainty about the amount of plutonium present in the vadose zone and the mobility of plutonium in INTEC soils.

INEEL scientists and engineers are investigating contaminant transport in the vadose zone and tank farm soils (see Figure 21). Cleanup work may be necessary in the future if the proposed water control methods are insufficient.

Some radionuclides that have contaminated the aquifer at the INTEC, such as tritium, have short half-lives. Their concentration in the aquifer is expected to diminish and meet their drinking water standards within 100 years. This assumes that substantial amounts do not continue to enter the aquifer from the vadose zone. However, iodine-129 has an extremely long half-life, and dilution and dispersion may not sufficiently diminish its concentration to meet drinking water standards within 100 years.

If drinking water standards are to be achieved within 100 years, groundwater modeling has determined that, in the year 2000, the iodine-129 concentration in the aquifer cannot exceed 11.4 pCi/L at the predicted zone of highest concentration. If this concentration is exceeded, additional studies to prepare for cleanup work will begin. If these studies find that the currently proposed cleanup plan would work, the plan would be implemented. Under the proposed cleanup plan, groundwater will be pumped from the zone of highest concentration using approximately 20 wells at a rate of about 1 gallon per minute in each well. Iodine-129 would be removed from the water using ion exchange. ❐

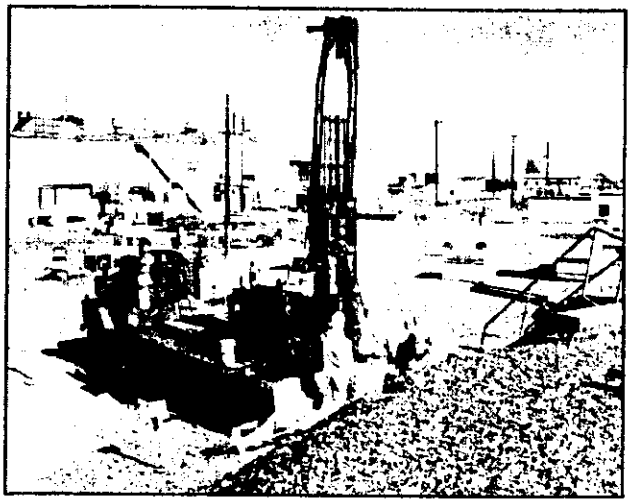
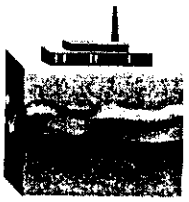


Figure 21. *Soil is sampled at the INTEC tank farm to determine the nature, extent, and spread of contamination.*

Central Facilities Area

Aquifer contaminants exceeding MCLs:

➡Nitrate



The Central Facilities Area was established during World War II to lodge U.S. Navy gunnery range personnel. During the 1950s, it was expanded to provide centralized support for the INEEL. Its facilities include administrative offices, research laboratories, a cafeteria, emergency and medical services, construction and support services, workshops, warehouses, and landfills.

The depth to the water table at the Central Facilities Area is approximately 480 feet. The local direction of aquifer flow is generally to the south-southwest. The aquifer's active portion is estimated at 250 to 820 feet in thickness. Aquifer flow velocity ranges from 5 to 20 feet per day. Local recharge to the aquifer is primarily through precipitation. No perched water zones are known to exist beneath the Central Facilities Area.

Types and Sources of Aquifer Contaminants

The aquifer contaminant at the Central Facilities Area whose concentration consistently exceeds drinking water standards is the inorganic chemical nitrate (see Figure 22). In addition to nitrate, lead has been detected in the aquifer at the Central Facilities Area and is currently under investigation. The level at which the Environmental Protection Agency requires cleanup activity is 10 ppb. A chromium plume that originated at the Test Reactor Area and a tritium plume that originated at the INTEC extend beneath the Central Facilities Area.

There appears to be another source of nitrate that originated at the Central Facilities Area in addition to minor quantities of nitrate which have migrated in the aquifer from the INTEC. This source of nitrate at the Central Facilities Area is not yet known. Current investigations suggest that the most likely source is a wastewater disposal pond at the Central Facilities Area. This pond received sodium nitrate, nitric acid, and uranyl nitrate from the Chemical Engineering Laboratory, which operated at the Central Facilities Area from 1953 to 1969. Nitrogen contained in these compounds may have transformed in the environment into nitrate. The pond is no longer in use.

Cleanup Activities

Because the source of the groundwater contamination is unknown, additional investigation is proposed to determine its source. Once a source for the contamination is identified, cleanup, if required, can begin. Cleanup of the contaminant plumes that originated at the Test Reactor Area and the INTEC are addressed by those areas. ❐

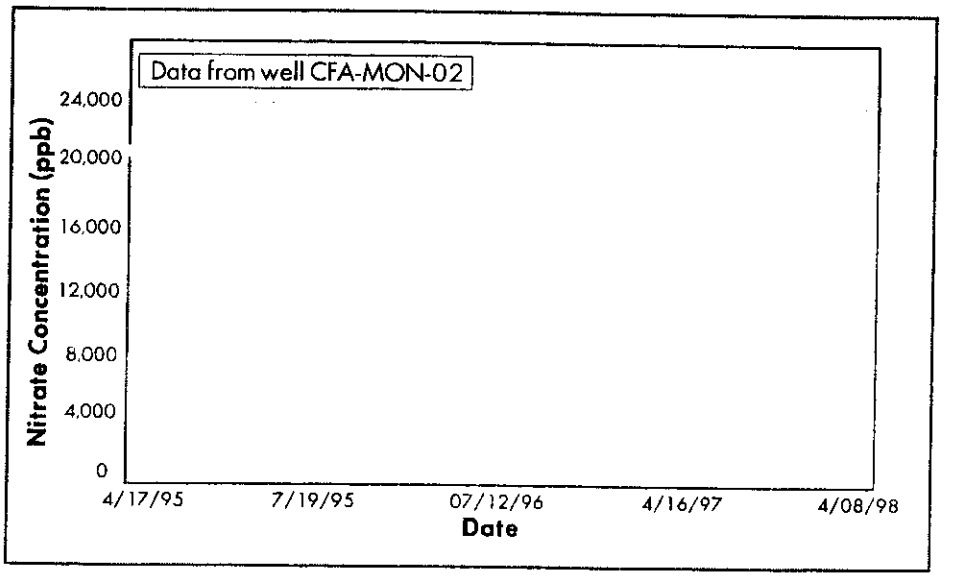


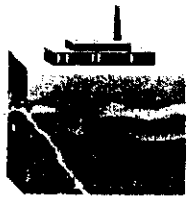
Figure 22. *The nitrate concentration in the aquifer at the Central Facilities Area exceeds drinking water standards (10,000 ppb). The source of the nitrate is unknown.*

Radioactive Waste Management Complex (RWMC)

Aquifer contaminants exceeding MCLs:

- Carbon tetrachloride
- Strontium-90

580 feet



The Radioactive Waste Management Complex (RWMC) was established in 1952 as a disposal site for waste contaminated with radionuclides, and prior to 1970, hazardous substances such as organic and inorganic chemicals. The RWMC is divided into three areas. The Subsurface Disposal Area dates to 1952 and was previously used to dispose of many types of waste. It is presently used only for low-level waste disposal. The Transuranic Storage Area began operating in 1970 and stores waste containing transuranic (very long-lived) radionuclides on a paved pad above ground. The third area is an administrative area, and consists of office buildings and support facilities.

Transuranic waste was buried beneath the ground surface at the RWMC from 1952 to 1970, and buried on an above-ground pad from 1970 to 1972. After 1972, transuranic waste was stored (for future disposal) at the Transuranic Storage Area. Transuranic waste is currently being shipped from the INEEL to the Waste Isolation Pilot Project (WIPP), a permanent geologic repository in New Mexico. Common constituents of transuranic waste are long-lived radionuclides of plutonium and americium, and hazardous components such as organic and inorganic chemicals.

Hazardous waste was disposed of at the Subsurface Disposal Area until 1970. Common constituents of this hazardous waste were metals (such as lead), organic chemicals (such as carbon tetrachloride), and acids, depleted uranium, and caustics. From 1966 to 1970, an estimated 90,000 gallons of containerized organic chemicals were disposed of at the Subsurface Disposal Area. The major components of the organic chemicals include 24,000 gallons of carbon tetrachloride, 25,000 gallons of TCE, PCE and 1,1,1-trichloroethane, and 39,000 gallons of Texaco Regal Oil (a lathe coolant).

The depth to the water table at the RWMC is approximately 580 feet. The thickness of the active portion of the aquifer is about 250 feet, and the bottom of the aquifer is 1,200 to 1,500 feet below the surface. The local direction of aquifer flow is generally to the south-southwest. Aquifer flow velocity varies from 5 to 20 feet per day.

Perched water zones have been encountered at depths of 80 to 100 feet and 180 to 230 feet beneath the Subsurface Disposal Area. These zones are believed to be recharged by precipitation, the Big Lost River, and three floods that occurred in 1962, 1969, and 1982. At present, very little water is contained in the perched water zones.

Types and Sources of Groundwater Contaminants

Contaminated groundwater at the RWMC is located in the perched water zones and the aquifer. Aquifer contaminants at the RWMC whose concentrations consistently exceed drinking water standards are the organic chemical carbon tetrachloride and the radionuclide strontium-90. Without cleanup work, currently underway, fate and transport modeling has predicted that concentrations of carbon tetrachloride, TCE, and PCE would increase in the aquifer, peaking around the year 2071 at 24, 20, and 12 times their MCLs, respectively.

In general, there is not enough water available in the perched water zones to adequately measure groundwater contamination. However, contaminants often detected in the deep perched water zone include the inorganic chemicals antimony, arsenic, beryllium, chromium, lead, and nickel; and the organic chemicals carbon tetrachloride, chloroform, TCE, and PCE.

The primary source of contaminants in the aquifer and perched water zones is the burial and breach of containerized waste at the Subsurface Disposal Area. The Transuranic Storage Area is not considered to pose a risk to the aquifer because it is specifically designed and managed to prevent the release of hazardous and radioactive substances to the environment.

Past waste disposal practices contributed to contamination of groundwater at the RWMC. Prior to 1970, solid and liquid waste were deposited in pits and trenches in steel drums, plywood crates, and cardboard boxes, and periodically covered with soil. From 1963 to 1969, in addition to these practices, transuranic waste was randomly dumped in pits rather than being stacked. Many of these containers were damaged during disposal and lost their integrity. Investigations have found that buried plywood crates and cardboard boxes have

deteriorated to the extent they have no remaining containment value, and rust and corrosive substances have perforated many steel drums.

Substances that have contaminated the aquifer at the RWMC have migrated through the vadose zone. Carbon tetrachloride and other organic chemicals including trichloroethene (TCE) and tetrachloroethene (PCE) continue to leak from buried waste at the RWMC. Carbon tetrachloride is highly mobile in soil and rock and is migrating both as a vapor, and as a liquid (see Figure 23). Other substances have been transported by precipitation and floodwater seeping into the vadose zone (see Figure 24). Dikes and other surface-water control structures have been built to prevent future floods from reaching the RWMC.

Laboratory and field tests indicate that plutonium strongly adheres to rock and soil types found at the INEEL. However, traces of plutonium have been detected in the aquifer beneath the RWMC. Concentrations have ranged from 0.02 to 0.05 pCi/L, compared to plutonium's drinking water standard of 5 pCi/L. Investigations are currently being conducted to determine the source of the plutonium in the aquifer at the RWMC.

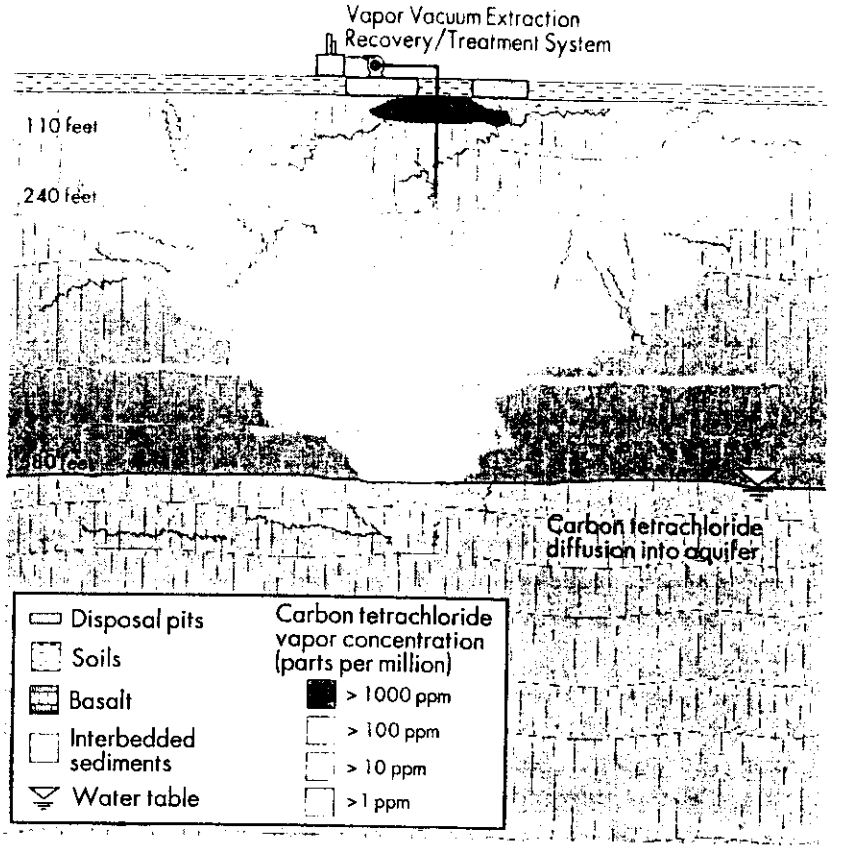


Figure 23. *Cross-section of the vadose zone at the Radioactive Waste Management Complex showing artist's rendition of carbon tetrachloride migration from buried waste to the aquifer (not to scale).*

Figure 24. *Water, flowing from the surrounding terrain (such as during this 1969 flood), has entered open excavations at the Radioactive Waste Management Complex and possibly leached contaminants from buried waste into the vadose zone. Dikes have been constructed to protect the complex from future floods.*

Cleanup Activities

Cleanup work is required to remove organic chemicals from the vadose zone beneath the RWMC to prevent concentrations of these chemicals in the aquifer from rising and exceeding drinking water standards. Strontium-90 concentrations in the aquifer will naturally diminish to meet drinking water standards within 100 years through decay, downgradient dilution, and dispersion. No cleanup action is required for strontium-90 other than continued monitoring of groundwater, 5-year environmental reviews, and institutional controls.

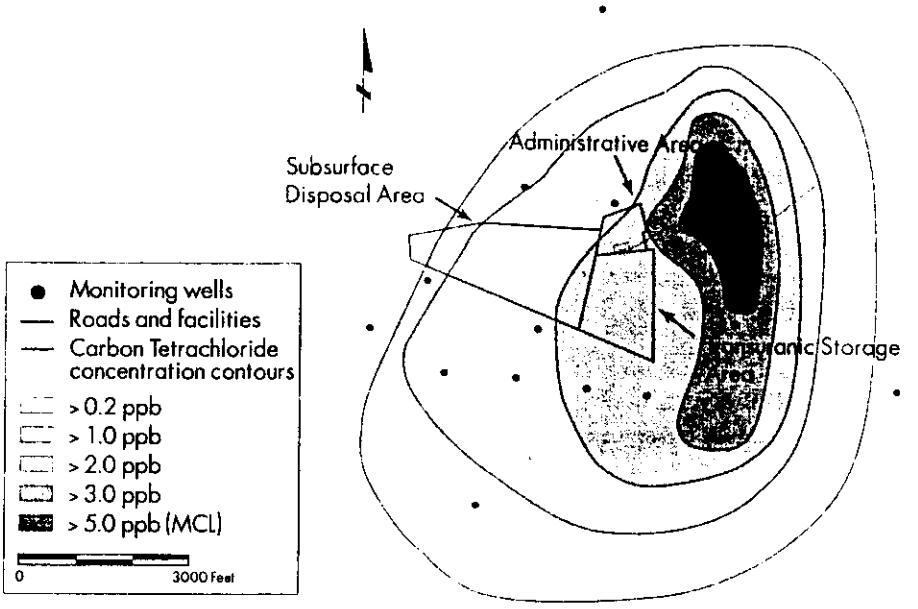


Figure 25. *Carbon tetrachloride is migrating in the aquifer at the Radioactive Waste Management Complex as a liquid.*

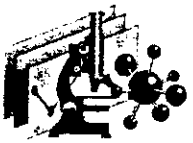
In 1996, the INEEL installed a vapor vacuum extraction system to begin removing organic chemical vapors from the vadose zone. Organic chemical vapors are vacuumed from wells drilled into the vadose zone, and destroyed by heating them. Destruction results in the formation of carbon dioxide, hydrogen chloride, and water vapor, which are released to the atmosphere. Since 1996, more than 3,700 gallons of organic chemicals have been extracted from the vadose zone and destroyed, compared to approximately 90,000 gallons known to have been buried at the RWMC. ❐

Comprehensive Aquifer Cleanup

The eastern Snake River Plain Aquifer does not start and stop at the borders of each INEEL facility, just as it does not start and stop at the INEEL's borders. Aquifer contamination that originated at some INEEL facilities has spread beneath other INEEL facilities, and contaminant plumes have merged. Though aquifer contamination may be within acceptable limits at individual facilities, all aquifer contamination must be examined for cumulative effects. Waste Area Group 10, which includes the eastern Snake River Plain Aquifer, addresses contamination issues that cross facility boundaries at the INEEL.

A separate comprehensive investigation into aquifer and groundwater contamination for the entire INEEL began in 1999, more than two years ahead of schedule. Completion is scheduled for 2004. The comprehensive investigation for the eastern Snake River Plain Aquifer will examine the cumulative effects of INEEL activities and contamination of the aquifer. The investigation will include studying the cumulative effects of long-lived radionuclide contamination. ❐

Technology Development and Research



Aquifer contaminant plumes at the INEEL typically consist of large volumes of slightly contaminated water. Some contaminants tend to remain in the aquifer when water is pumped out and some contaminants are not easily separated from water. In many instances, the contaminants are so dilute and the amount of contaminated water so large that existing methods for removing the contaminants are either very expensive or technically infeasible.

Scientists and engineers at the INEEL are currently developing several new technologies to improve groundwater cleanup. Some of these technologies will improve monitoring of groundwater contamination and contaminant migration (see Figure 26). Other technologies use enhanced natural processes to clean up groundwater. For example, bacteria are being used to break down trichloroethene and other organic chemicals at Test Area North (see Figure 27).

New technologies under study include sequestration of contaminants in the aquifer. If groundwater contaminants can be sequestered (held) in place, the potential risks to downgradient water users are minimized. Sequestration technologies are particularly attractive for reducing risks posed by short-lived radionuclides, because many of these radionuclides will decay to innocuous substances within several decades. Strontium-90, which has a relatively short half-life of 29 years, will travel with groundwater, but when bound to solids it will remain in place.

A sequestration method currently under study at the INEEL uses bacteria that naturally occur in the groundwater. When a common agricultural fertilizer is injected into the aquifer, the bacteria breaks down the fertilizer to innocuous substances and temporarily makes the groundwater slightly less acidic. When the water becomes less acidic, dissolved calcium salts in the aquifer precipitate as a solid. Strontium-90 readily binds to the precipitated calcium solids. The calcium solids remain in place in the aquifer instead of traveling with the groundwater, binding strontium-90 while it decays. Strontium-90 decays to zirconium, which has no biological role and is used for artificial joints and limbs. This sequestration technology may also work to bind metals such as barium, cadmium, nickel, and zinc.

A similar biotechnology under development uses bacteria to change Chromium-VI, present in contaminated groundwater throughout the world, to Chromium-III, a form that is much less hazardous to human health. ❐

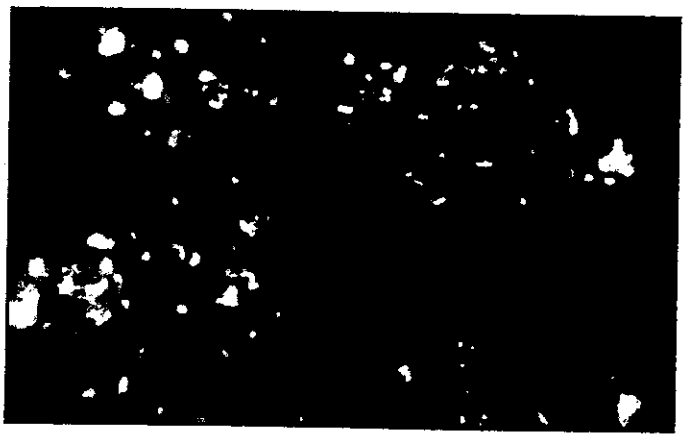


Figure 27. *Photomicrograph of aquifer bacteria at Test Area North. These bacteria can break down organic chemicals into innocuous substances.*

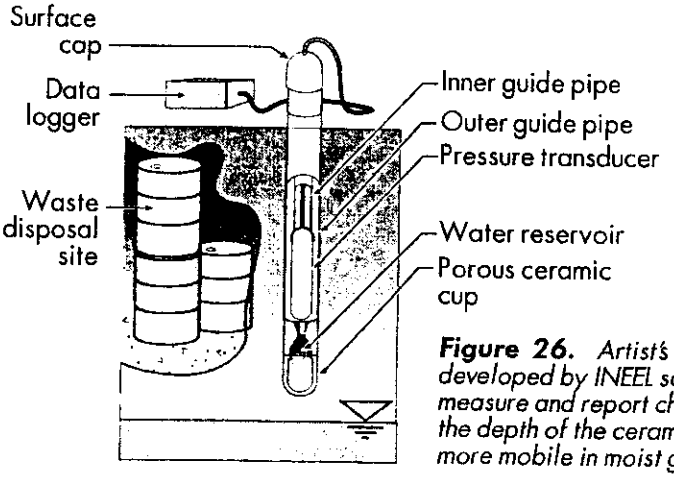


Figure 26. *Artist's rendition of Advanced Tensiometer developed by INEEL scientists and engineers. Tensiometers measure and report changes in soil and rock moisture content at the depth of the ceramic cup (not to scale). Contaminants are more mobile in moist ground than dry ground.*

Bibliography

Information on aquifers, groundwater, the eastern Snake River Plain Aquifer, and groundwater contamination at the INEEL can be found in many sources. The following publications were used in part to prepare this fact sheet, and are useful reference sources.

Nuclear Processes and Environmental Contamination

Excellent descriptions of how nuclear processes led to environmental contamination, including at the INEEL, are found in the following publications:

Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes To Their Environmental Consequences (January 1997). Office of Environmental Management, U.S. Department of Energy.

Closing the Circle on the Splitting of the Atom (1996). Office of Environmental Management, U.S. Department of Energy.

Both documents, and others, are available free of charge by writing The Environmental Management Information Center, U.S. Department of Energy, 1000 Independence Avenue SW, Washington, D.C. 20585, or by calling (800) 736-3282.

Aquifers and Groundwater

For more information on aquifers, the Environmental Protection Agency Office of Groundwater and Drinking Water has numerous publications available, plus internet sites with many resources. Contact the EPA at (800) 490-9198, or on the Internet at **www.epa.gov**. Other sources are:

- Drinking water information **www.epa.gov/OGWDW**
- Aquifer information **www.epa.gov/seahome/groundwater/src/geo1.htm**

The Snake River Plain Aquifer

The geology, hydrology, and uses of the eastern Snake River Plain Aquifer are described in the following publications:

Geologic Story of the Eastern Snake River Plain and the Idaho National Engineering Laboratory. Bill Hackett, Jack Pelton and Chuck Brockway, U.S. Department of Energy, Idaho Operations Office, November 1986.

Exploring Idaho Geology. Terry Maley, 1987, Mineral Land Publications, P.O. Box 1186, Boise, Idaho, 83701.

Geology of the Pacific Northwest. Elizabeth L. and William N. Orr, 1996, Mc-Graw Hill, New York.

Roadside Geology of Idaho. David D. Alt and Donald W. Hyndman, 1989, Mountain Press Publishing Company, P.O. Box 2399, Missoula, Montana 59806.

Summary of the Snake River Plain Regional Aquifer-System Analysis in Idaho and Eastern Oregon. G. F. Lindholm, U.S. Geological Survey Open-File Report 91–98, 1993, Boise, Idaho.

Water Use on the Snake River Plain, Idaho and Eastern Oregon. S. A. Goodell, U.S. Geological Survey Open-File Report 85-559, 1986, Boise, Idaho.

Upper Snake River Basin Study, 1997. Idaho Department of Water Resources, 1301 N. Orchard Street, Boise, Idaho 83720.

Drinking Water Contaminants and Standards

Comprehensive technical and consumer information on drinking water contaminants found at the INEEL is available at the following Internet sources:

- Current EPA drinking water standards **www.epa.gov/OGWDW/wot/appa.html**
- EPA contaminant fact sheets **www.epa.gov/OGWDW/hfacts.html**
- EcoIndiana contaminant fact sheets **netdirect.net/~ecoindy/chems**

Groundwater Contamination at the INEEL

Public documents issued by the INEEL were used in preparing this document, including Proposed Plans, Records of Decision, fact sheets, and other reports which are contained in the INEEL's Administrative Record. The Administrative Record is at **ar.inel.gov/home.html**

A highly useful document that addresses groundwater contamination on a site-wide basis at the INEEL is:

Idaho National Engineering Laboratory Groundwater Monitoring Plan (2 vols.). June 1993, Idaho National Engineering Laboratory, U.S. Department of Energy, Idaho Operations Office.

Many of the documents used to prepare this fact sheet, as well as related documents, are available to the public in the INEEL Administrative Record. The record is available on the Internet at **ar.inel.gov/home.htm** or at the following locations:

INEEL Technical Library
DOE Public Reading Room
1776 Science Center Drive
Idaho Falls, ID 83415
208-526-1185

Albertsons Library
Boise State University
1910 University Drive
Boise, ID 83725
208-385-1621

University of Idaho Library
University of Idaho Campus
434 2nd Street
Moscow, ID 83843
208-885-6344

Citizens can request additional information or schedule a briefing on groundwater and aquifer contamination at the INEEL. Briefings can focus on site-wide groundwater issues or groundwater contamination at individual INEEL facilities. To schedule a briefing or a tour of the INEEL, please call the INEEL Community Relations representatives, or the INEEL toll-free phone number, 800-708-2680.

An INEEL Regional Office is located in western Idaho and can also provide information and other resources. The address and phone number are:

INEEL Regional Office
805 West Idaho Street
Suite 301
Boise, ID 83703
208-334-9572

Environmental Management Program